

**Westside Type F Riparian Prescription Monitoring Project- Exploratory Field Study
Draft Study Plan-December 4, 2017**

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Definition of acronyms used in the Westside Type F Study Design Discussion:

CMER- Cooperative Monitoring, Evaluation and Research Committee. The Cooperative Monitoring, Evaluation, and Research (CMER) Committee is a monitoring, evaluation, and research program established by the Forest Practices Board. Its purpose is to ensure effective implementation of the recommendations contained in the Forests and Fish Report.

FPA- Forest Practice Application. A permit required to conduct most forest practices activities on state or private forest land in Washington State.

DFC- Desired Future Condition. Refers to the condition of a forest at 140 years, with respect to age of trees, canopy cover, downed logs, etc. The goal of the Forests & Fish riparian management strategy is to leave the riparian area in a condition today that is on a trajectory to replicate the conditions of natural stands of forest at age 140.

FPHCP- Forest Practices Habitat Conservation Plan. The purpose of the FPHCP is to provide programmatic “coverage” under the Washington Department of Natural Resources (WDNR) forest practices division regulating private forestlands, and eastern WA state lands. Landowners who conduct forest practices activities that are in compliance with the Forest Practices Act and rules will meet the requirements of the Federal Endangered Species Act for “listed” species under the FPHCP (i.e., certain freshwater fish species and some stream associated amphibians). The HCP seeks to provide for the protection and long-term conservation of aquatic designated species, meet Clean Water Act requirements, and support the restoration and conservation of riparian habitat. The FPHCP is also supposed to provide for the restoration of harvestable levels of salmon while maintaining an economically viable timber industry.

LTCW-Leave trees closest to the water. An inner zone harvest strategy that involves of harvesting trees furthest from the water and leaving those closest to the water.

RMZ- Riparian Management Zone. An area protected on each side of a Type F or S Water.

TBF- Thin from below. An inner zone harvest strategy of harvesting smaller diameter trees and leaving the larger trees.

Type F Water- Segments of natural waters that contain fish habitat (other than Type S waters).

Type S Water- All waters inventoried as shorelines of the state under the state Shorelines Management Act; also waters containing fish habitat.

1 Background

2 Westside Type F and S Prescriptions

3 The westside Type F and S riparian prescriptions are an important component of the Riparian
4 Conservation strategy of the Washington Forest Practices Habitat Conservation Plan (FPHCP)
5 (WDNR 2005). The Riparian Conservation Strategy of the FPHCP focuses on protection of
6 riparian habitat and processes to meet water quality standards and support recovery of aquatic
7 and riparian dependent species such as fish and stream-associated amphibians. Riparian forests
8 covered by these prescriptions are adjacent to waters fish use for spawning, incubation, and
9 rearing. Habitat for fishes is directly affected by the functions, processes, and inputs provided
10 by these forests including litter fall, shade, long-term wood recruitment, bank protection, and
11 sediment filtering.

12 The FPHCP identifies Resource Objectives, which are key aquatic conditions and processes
13 affected by forest practices (http://www.dnr.wa.gov/Publications/fp_hcp_31appn.pdf). The
14 Westside Type F and S riparian prescriptions help achieve the resource objectives for
15 heat/water temperature, large wood/organic inputs, and sediment by providing shade to
16 maintain cool water temperatures and a source of large wood and organic material to create
17 aquatic habitat, and by preventing input of sediment from timber harvest operations.

18 The Westside Type F and S riparian prescriptions establish riparian management zones (RMZs)
19 adjacent to the stream (Washington Forest Practices Board 2012). The RMZ consists of three
20 zones oriented parallel to the edge of the bankfull channel (Figure 1). Closest to the stream is
21 the 50 ft wide core zone where no harvest is allowed. Beyond the core zone lies the inner zone,
22 which varies in width depending on site class and stream width category. Some harvest is
23 allowed within the inner zone if stocking is adequate to meet the desired future condition (DFC)
24 performance target (WFPB 2012, WAC 222-30-021). Inventory data from the core and inner
25 zone are used to run a stand growth model that predicts whether the stand will achieve the
26 DSC target of 325 sq ft of basal area per acre at 140 years of age (McConnell 2007). If basal area
27 is sufficient, the model identifies excess trees that can be harvested from the inner zone. In
28 cases where inner zone harvest is allowed, landowners can use harvest option 1, thin from
29 below, or in some cases use option 2, leave trees closest to the water. Where the DFC target
30 will not be met, or where inner zone harvest is not economically or logistically feasible, no inner
31 zone harvest occurs. Beyond the inner zone lies the outer zone. Landowners are required to
32 leave 20 trees/acre in the outer zone and can choose whether to clump or disperse the leave
33 trees.

34 The prescribed width of RMZs for westside Type F and S streams varies according to five site
35 class categories, two channel bankfull width categories and three harvest options (Table 1).
36 Given the possible combinations there are 25 potential variations of the westside Type F
37 standard rules, hereafter referred to as prescription variants.

38

39

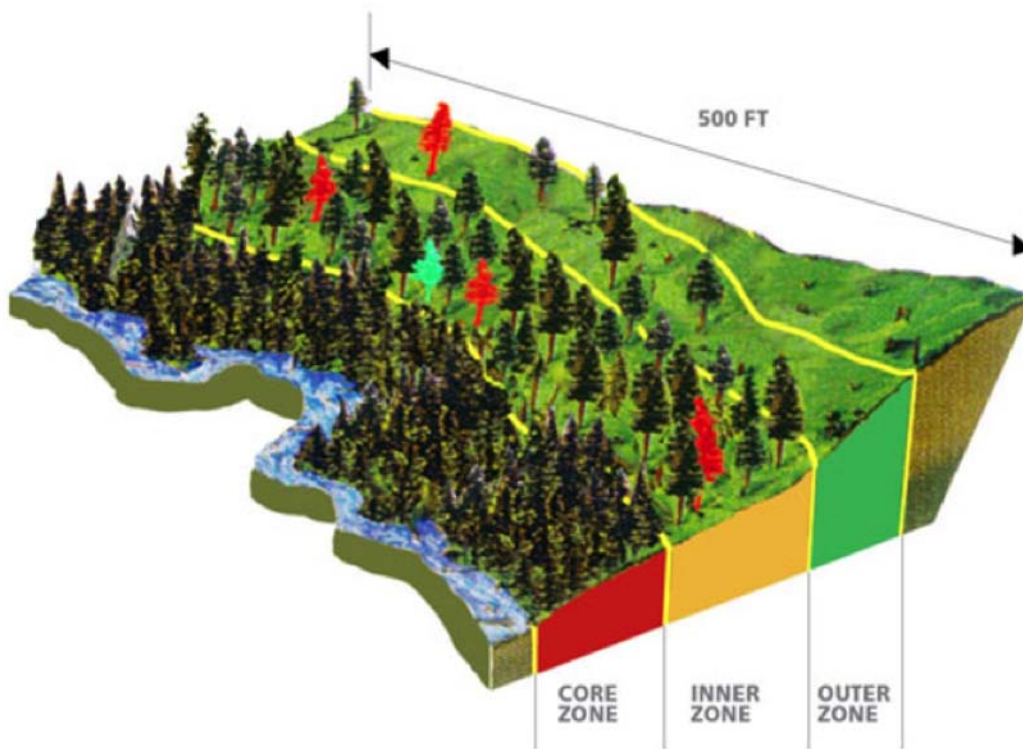
40 Table 1. Description of site class categories, stream width categories and harvest options used
41 in the western Washington Type F and S riparian prescriptions (WFPB 2016).

Site Class Categories	50-year site index range (tree height in feet)
I	137+
II	119-136
III	97-118
IV	76-96
V	<75

Stream width categories	Description
Large stream	>10 feet bankfull width
Small stream	≤10 feet bankfull width

Harvest options	Description
Option 1	Thin from below (TFB)
Option 2	Leave trees closest to water (LTCW)
No-inner-zone-harvest	Leave all trees

42



43

44 Figure 1. Diagram of the western Washington Type F Riparian Management Zone layout,
45 showing the core, inner and outer zone. Colored trees indicate trees retained for wildlife.

46 **Westside Type F Riparian Prescription Monitoring Project**

47 The effectiveness of the Westside riparian prescriptions for F and S streams in achieving the
48 FPHCP resource objectives and performance targets has not been evaluated. The CMER
49 Workplan (CMER 2015; http://www.dnr.wa.gov/publication/bc_cmer_workplan_2015.pdf)
50 identified the need for research to examine the effectiveness of RMZ rules and to provide
51 information that is necessary to inform the FPHCP adaptive management program. In 2015,
52 CMER established a Technical Writing and Implementation Group (TWIG) to conduct scoping
53 and develop a research approach for assessing Type F riparian prescription effectiveness
54 (Schuett-Hames et al. 2015).

55 The TWIG identified an intensive before-after-control-impact (BACI) study as our preferred
56 approach to answer questions about causal linkages between the prescriptions, changes in
57 riparian stand structure and inputs/functions, and the responses of stream habitat, water
58 quality, and aquatic biota (Schuett-Hames et al. 2015). Due to the large number of different
59 prescription variants and uncertainty about how frequently they were used and how the
60 prescriptions influence post-harvest riparian stand structure and functions, we determined that
61 more information was needed to develop an effective, focused, and efficient design for the
62 intensive BACI study. Consequently, we proposed to conduct two preliminary information
63 gathering steps prior to designing the intensive study: 1) an analysis of approved forest practice
64 applications and GIS data (the FPA/GIS analysis) to determine the implementation frequency of
65 different prescription variants and the size and spatial distribution of riparian harvest units on
66 the landscape, and 2) an exploratory field study to examine post-harvest stand characteristics
67 and riparian functions associated with various prescription variants. The FPA/GIS analysis (step
68 1) has been completed. The results are presented in Appendix A and have been used to design
69 the exploratory study. This document contains the proposed study design for the exploratory
70 field study.

71 The exploratory study is intended reduce uncertainties associated with the relative sensitivity
72 of post-harvest riparian stand conditions and riparian functions to potential disturbances
73 associated with the prescription variants and to provide an estimate of effect size for some
74 metrics. Information on the magnitude of differences between prescription variants will be
75 used to inform and guide the design of the intensive BACI study. In addition, stand structure
76 data and soil disturbance data will be used to provide an estimate of the proportion of sites
77 meeting FPHCP performance targets.

78 **Exploratory Field Study Design**

79 The exploratory field study will assess riparian stand conditions and selected riparian functions
80 across a wide range of prescription variants and site conditions. It will provide a coarse-level

81 assessment of current riparian conditions that focuses on addressing scientific uncertainty
82 surrounding their sensitivity to current forest practices expressed as prescription variants. This
83 is not a designed experiment but an exercise in collecting pilot data for riparian prescriptions
84 that are already distributed across the landscape. With adequate funding, we estimate this
85 exploratory study will be completed in approximately three years. At the conclusion, we will
86 have information for most of the westside Type F prescription variants including:

- 87 • the level of riparian functions associated with the prescriptions, including data on post-
88 harvest large wood recruitment, shade, and sediment delivery,
- 89 • riparian stand conditions associated with the prescriptions, including stand mortality,
90 density, basal area, and the proportion of sites currently on trajectory to meet DFC
91 target of 325 ft²/acre of basal area at 140 years,
- 92 • the frequency, magnitude and distribution of windthrow and its effects on stand
93 structure, buffer tree mortality rates and riparian functions,
- 94 • the relative influence of differences in site conditions and geographic location on the
95 above.

96 **Goal and objectives of the Exploratory Study**

97 The overall goal of the exploratory study is to produce information needed to focus and design
98 the BACI study.

99 The objectives of the exploratory study are:

- 100 1. To evaluate post-harvest riparian stand conditions and riparian ecological functions
101 across prescription variants with and without inner zone harvest.
- 102 2. To evaluate the extent to which post-harvest riparian forest stands are on trajectory to
103 achieve DFC targets at sites with and without inner zone harvest.

104 **Exploratory Study Approach**

105 The exploratory study will collect data after impact (AI) to provide a landscape-scale, coarse-
106 level assessment of post-harvest riparian stand structure and riparian functions, and to
107 evaluate whether stands are on trajectory to meet DFC targets three years after harvest. We
108 considered using an after-control-impact (ACI) approach, but rejected it because it requires a
109 substantial effort to obtain and sample an appropriate reference population. The proposed AI
110 approach enables us to maximize the number of treatment sites that can be sampled, which
111 will improve our ability to detect, distinguish and assess measurable patterns in post-harvest
112 conditions across treated sites. While a reference population and/or pre-treatment data would
113 be essential for attributing observed conditions to treatments, e.g., attributing causation, that
114 is not our goal and these data will not be used to compare harvested versus unharvested areas.

115 **Population of Interest**

116 The population of interest consists of riparian stands in the core and inner zones of RMZs
117 adjacent to fish-bearing streams harvested according to the current standard riparian
118 prescriptions for western Washington Type F and S streams (Figure 2 and Table 2). Because the
119 minimum basal area thresholds controlling harvest under the forest practices rules and
120 regulations were changed in 2006, the population of interest only includes activities approved
121 under the new rules (WAC 222-30-021; http://file.dnr.wa.gov/publications/fp_rules_ch222-30wac.pdf). The population of interest excludes stands harvested using alternative riparian
122 prescriptions, such as practices covered under hardwood conversion rules, 20-acre exempt
123 parcel rules, alternate plans, and landowner-specific habitat conservation plans (HCPs). Riparian
124 stands with channel migration zones (CMZs) or stream adjacent roads are excluded because
125 they are regulated under separate provisions of the forest practice rules.
126



127
128 Figure 2. Approximate area covered by the Forest Practices rules in western Washington.

129 Table 2. Frequency distribution of stream segments with RMZs harvested according to Westside
 130 Type F prescription variants. Based on random sample of 170 FPAs and 590 associated stream
 131 segments with effective dates between July 2008 and June 2013 (see Appendix A for details).

Site Class	Prescription Variant		Core & Inner Zone No Harvest Width (ft)	Minimum Basal Area (ft ² /acre)	Stream Segment Count	Percent*
	Stream Width Category	Harvest Treatment				
I	large	No inner zone harvest	150	No Minimum	8	1.4%
I	large	Option 1- TFB	150	325	0	0.0%
I	large	Option 2- LTCW	100+	325	11	1.9%
I	small	No inner zone harvest	133	No Minimum	6	1.0%
I	small	Option 1- TFB ¹	133	325	0	0.0%
I	small	Option 2- LTCW ²	80+	325	7	1.2%
II	large	No inner zone harvest	128	No Minimum	52	9.0%
II	large	Option 1- TFB ¹	128	325	0	0.0%
II	large	Option 2- LTCW ²	100+	325	24	4.1%
II	small	No inner zone harvest	113	No Minimum	59	10.2%
II	small	Option 1- TFB ¹	113	325	4	0.7%
II	small	Option 2- LTCW ²	80+	325	13	2.2%
III	large	No inner zone harvest	105	No Minimum	86	14.8%
III	large	Option 1- TFB ¹	105	325	31	5.3%
III	small	No inner zone harvest	93	No Minimum	107	18.4%
III	small	Option 1- TFB ¹	93	325	8	1.4%
III	small	Option 2- LTCW ²	80+	325	94	16.2%
IV	large	No inner zone harvest	83	No Minimum	15	2.6%
IV	large	Option 1- TFB ¹	83	325	0	0.0%
IV	small	No inner zone harvest	73	No Minimum	6	1.0%
IV	small	Option 1- TFB ¹	73	325	0	0.0%
V	large	No inner zone harvest	68	No Minimum	19	3.3%
V	large	Option 1- TFB ¹	68	325	0	0.0%
V	small	No inner zone harvest	60	No Minimum	30	5.2%
V	small	Option 1- TFB ¹	60	325	0	0.0%

132 ¹Thin from below ² Leave trees closest to the water

133 **Experimental Unit**

134 A single FPA can have several Type F or S streams with multiple segments based on site class
 135 and stream width category, each with different prescriptions. The landowner can choose to
 136 break streams into separate segments with different harvest strategies based on stand
 137 characteristics and operational considerations. Consequently, the experimental unit is a Type F
 138 or S RMZ segment with a consistent DNR site class (I, II, III, IV or V), stream width category and
 139 harvest option.

140 **Stratification and Sample Size**

141 We propose to stratify sampling by prescription variant, which differ in buffer width and leave
 142 tree requirements according to site class (tree growth potential), stream size category and
 143 harvest treatment (Table 3). These differences are expected to influence riparian stands and
 144 riparian functions post-harvest. Since one goal of the pilot project is to help focus the BACI
 145 study on prescription variants where there is evidence of a response to treatment, we want to
 146 survey as many prescription variants as possible. However, due to the budget constraints, we
 147 propose limiting sampling to the eleven prescription variants that are present in substantial
 148 amounts across the landscape (Table 3). We eliminated seven variants that did not occur in our
 149 sample and another seven which each represented <2% of the total. Together, the excluded
 150 prescription variants represented <10% of the population.

151 Table 3. Eleven prescription variants (strata) to be sampled with proposed sample allocation.

Site Class	Prescription Variant		Core & Inner Zone Width (ft)	Minimum Basal Area (ft ² /acre)	Stream Segment Count	% total stream segments*	Proposed Sample Allocation
	Stream Width Category	Harvest Treatment					
II	large	No inner zone harvest	128	No Minimum	52	9.0%	10
II	large	Option 2- LTCW ¹	100+	325	24	4.1%	10
II	small	No inner zone harvest	113	No Minimum	59	10.2%	10
II	small	Option 2- LTCW ¹	80+	325	13	2.2%	10
III	large	No inner zone harvest	105	No Minimum	86	14.8%	10
III	large	Option 1- TFB ²	105	325	31	5.3%	10
III	small	No inner zone harvest	93	No Minimum	107	18.4%	10
III	small	Option 2- LTCW ¹	80+	325	94	16.2%	10
IV	large	No inner zone harvest	83	No Minimum	15	2.6%	10
V	large	No inner zone harvest	68	No Minimum	19	3.3%	10
V	small	No inner zone harvest	60	No Minimum	30	5.2%	10

152 ¹Thin from below, ² Leave trees closest to the water, * Data from the FPA-GIS analysis (Appendix A).

153
154 For practical reasons, we propose limiting our sample size to approximately 110 samples. To
155 enable statistical analyses and provide even information across the prescription variants, we
156 propose to sample the same number ($n = 10$) of RMZ segments in each prescription variant
157 (Table 3). Given that some prescription variants are relatively rare and others are relatively
158 common, a simple random sample would run the risk of creating too much or too little
159 information about one particular treatment variant. The proposed stratified scheme will collect
160 equal information across the selected set of treatment variants (Table 3).

161
162 A power analysis was conducted using data from the Westside Type N BCIF study (Schuett-
163 Hames et al., 2012) which compared unharvested and harvested stands with 50ft no-cut buffers
164 on headwater streams (See Appendix B). While this exploratory study will not be focusing on
165 statistical testing, a power analysis can inform whether we have an unreasonably high or low
166 sample size and can also serve as a reminder to avoid certain types of statistical testing. The
167 results showed that the power to detect differences varies depending on the variable of
168 interest and that a sample of $N = 10$ may be weak for comparing between two prescription
169 variants. While a sample size of 10 per strata is not ideal for every variable (mortality in
170 particular, see Appendix B), this sample size is likely to provide reasonable estimates across
171 treatments for other variables of interest such as basal area/acre or shade in this or future
172 studies.

173
174 The selected sampling strategy has two clear benefits: 1) less common prescription variants will
175 be equally represented in the analysis across strata, and 2) fine-scale analysis at the strata-scale
176 will be possible. Clearly, a larger sample size per strata would be preferable (see Appendix B).
177 However, the goals of the pilot project are not specifically related to strata (e.g., site class and
178 stream width divisions), but to broader definitions of harvest prescriptions (e.g., inner-zone-
179 harvest, no-inner-zone-harvest). Therefore, this approach will allow for representation of less
180 common, but potentially more sensitive, harvest prescriptions in the sample set used for
181 comparison. Additionally, we recognize the results of the power analysis (Appendix B) are only
182 a general indication of how data may look as there is no guarantee that the data we observe in
183 the proposed study will be similar in terms of distribution as the test data. Therefore, the
184 proposed sampling strategy is viewed as a starting point for quantifying and comparing the
185 prescription variants commonly applied on Type F and S streams in western Washington and
186 will be essential for conducting refined power analyses to inform the BACI design for the full
187 study.

188 **Sampling Strategy**

189 **Site Selection and Screening**

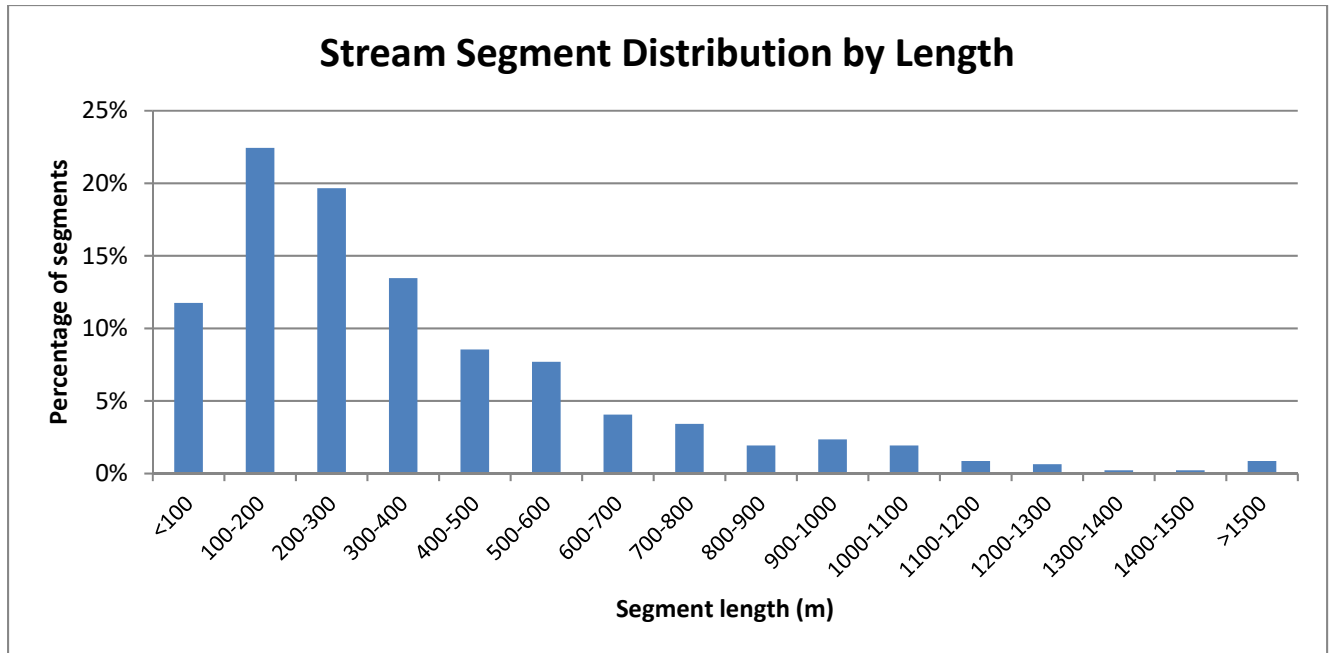
190 We identified five site selection criteria which will be used to include or eliminate RMZ
191 segments from the study due to their potential to confound our ability to detect treatment
192 effects. These include time since harvest, stream length, presence of channel migration zones
193 (CMZs), stream-adjacent parallel roads, and one- or two-sided buffers. Factors that only affect a
194 portion of a RMZ segment, such as the presence of road crossings or unharvested areas with
195 mass wasting or wetlands buffers, were not used to exclude sites. In these cases, the affected
196 portion of the RMZ segment will not be surveyed, but the remainder will be included in the
197 study, as long as it meets the minimum stream length criterion.

198 **Site selection criteria**

199 **Time since harvest.** We propose to sample sites that were harvested three winters prior to
200 sampling. We propose this time frame because research shows that post-harvest windthrow in
201 newly harvested buffer strips generally peaks within a few years after logging (Harris 1989,
202 Bahuguna et al. 2010, Schuett-Hames et al. 2012). Over time, windthrow mortality generally
203 declines as the surviving trees grow more wind firm (Ruel et al. 2001, Bahuguna et al. 2010,
204 Mitchell 2013). However, buffer strips remain vulnerable to impacts from severe storm events
205 which can also cause high mortality in unharvested stands (Ruel et al. 2001, Schuett-Hames et
206 al. 2012). Therefore, the post-harvest sampling schedule is designed to allow time for the newly
207 established buffers to be exposed to natural wind disturbances. Also, the three year delay is
208 soon enough after harvest to enable differentiation of pre- versus. post-harvest tree mortality
209 and recent wood recruitment (see “Fallen trees and large wood recruitment” section). We
210 recognize the short post-harvest time frame limits our assessment of mortality and changes in
211 stand structure that affect stand trajectory to meet the DFC target over longer timeframes and
212 a greater range of natural disturbance. However, the study time frame will provide a useful
213 assessment of the initial impacts of post-harvest mortality which can affect long-term trends in
214 riparian functions (e.g., Martin and Shelly 2017) and change in the ability of stands to achieve
215 the DFC target at year three post-harvest.

216
217 **Segment length.** There is substantial variation in the length of RMZ segments for a given
218 prescription variant (Figure 3). Because response variables such as canopy closure and wood
219 recruitment may be heavily influenced by adjacent unharvested stands we propose to locate
220 study reaches in harvested segments ≥ 150 m in length. This minimum length will eliminate
221 about 15% of harvested segments in the study population. See below for more details about
222 study site layout.

223



224

225 Figure 3. Distribution of stream segments from the FPA-GIS analysis by segment length (m).

226

227 **Channel migration zones.** RMZ segments with channel migration zones (CMZs) will be
 228 eliminated from the study. CMZs are areas adjacent to the stream where the active channel is
 229 prone to move, which are identified using criteria in the Forest Practices Board manual. The
 230 presence of a CMZ is noted on the FPA, and a separate no-harvest prescription is applied to the
 231 entire CMZ. The RMZ begins at the outer edge of the CMZ, so in effect, streams with CMZs
 232 receive a variable width buffer that exceeds the standard RMZ buffer. Approximately 2% of
 233 RMZ segments had CMZs.

234

235 **Stream-adjacent parallel roads.** RMZ segments with stream-adjacent parallel roads will be
 236 eliminated from the study. These are roads that go through the core or inner zones in a
 237 direction parallel to the alignment of the stream. In these cases, separate site-specific rules
 238 apply. Approximately 2% of the FPAs had stream-adjacent roads.

239

240 **One- vs. two-sided harvest.** Many harvest units are laid out with larger Type F or S streams as
 241 harvest unit boundaries. In these cases the stand on one side of the stream receives the
 242 riparian prescription and the stand on the other side does not. However, when a Type F stream
 243 lies within the harvest unit, harvest with a prescription buffer occurs on both sides of the
 244 stream. We surveyed 346 Type F or S segments from the FPA-GIS analysis to determine the
 245 proportion with one- and two-sided harvest for each of 10 stream width and site class
 246 combinations (Table 4). Two-sided harvest occurred less frequently than one-sided harvest,
 247 ranging from 8.3% to 50% of the segments. Less than 30% of the segments had two-sided

248 harvest in 7 of the 10 stream width/site class categories. Two-sided harvest tended to occur
 249 more frequently in small stream categories.

250
 251 This poses a sampling dilemma because some response variables, such as canopy closure are
 252 influenced by stands on both sides of the stream. Where the harvest prescriptions are done on
 253 only one side of the stream, these variables could be affected by riparian stand conditions on
 254 the opposite side which were likely harvested at various times under different prescriptions.
 255 This variability could confound our ability to associate riparian functions with the current
 256 prescription. On the other hand, it may be difficult to find an adequate sample of stream RMZ
 257 segments with two-sided harvest for some prescription variants.

258
 259 Table 4. Proportion of Type F RMZ segments with one- vs. two-side harvest by stream width
 260 and site class grouping.

Stream Width	Site Class	Number of Segments	% with 2 sided harvest
>10ft	I	12	8.3%
	II	52	28.8%
	III	72	16.7%
	IV	6	16.7%
	V	9	33.3%
≤10ft	I	9	11.1%
	II	40	37.5%
	III	132	36.4%
	IV	4	25.0%
	V	10	50.0%
All combined	-	346	29.5%

261
 262 After careful consideration, we designate only one side of a stream as the sample unit. We will
 263 include RMZ segments with both one- and two-sided treatments in the sample frame, but if a
 264 segment with a two-sided treatment is selected, one side will be chosen at random. Our
 265 rationale includes the following:

- 266 - including both one- and two-sided segments provides the largest sample frame with eligible
 267 sample units;
- 268 - the larger sample frame is more representative of the wide range of physiographic
 269 conditions on the landscape;
- 270 - there is variability in site conditions on the opposite bank, such as slope, aspect, or wind
 271 exposure, that have the potential to complicate or confound a two-sided analysis; and
- 272 - one-sided sample units facilitate more efficient allocation of field effort and allowing
 273 inclusion of more sample units for budget because a two-sided buffer requires double the
 274 effort per sample unit.

275
276 Where possible, we have attempted to structure the data collection to minimize confounding
277 effects due to stand conditions on the opposite side of the stream (see Methods).

278
279 The presence of yarding corridors and the outer zone harvest strategy will not be used to
280 exclude sites but will be treated as covariates. Yarding corridors consist of strips where trees
281 are removed to allow logs to be transported across the stream. They are considered to be part
282 of the RMZ harvest prescription and will be included when they occur in a study reach. The
283 outer zone is the next band beyond the inner zone (Figure 1). Landowners are required to leave
284 20 trees/acre in the outer zone and can choose whether to clump or disperse the leave trees.
285 We anticipate that the outer zone leave tree configuration will have little effect on the
286 response variables, due to the small number of trees and the distance from the stream.

287 **Randomized Sampling Procedure**

288 The sampling frame for each prescription variant in Table 3 will be assembled from approved
289 forest practice applications (FPAs) in the WDNR Forest Practices Application Review System
290 (FPARS) database using the procedures described in detail in Appendix C. Each entry in the
291 sampling frame will be a single RMZ segment that has been treated with a single prescription
292 variant and is at least 150 m in length. To minimize the potential for spatial autocorrelation,
293 only one FPA/RMZ segment will be accepted in each USGS Hydrologic Unit.

294 Prior to acceptance of a site in the sample frame, the landowner will be contacted to verify the
295 harvest timing and obtain permission to visit the site. Next, a field visit will be conducted to
296 verify that the harvest occurred as specified on the FPA, there is no CMZ or stream adjacent
297 roads, and the RMZ segment is long enough to support a study reach.

298 **Study Reach Layout**

299 We propose a fixed study reach length of 100 m with each portion of the RMZ segment having
300 an equal probability of being sampled. As such, we propose a random starting location at 25m
301 increments. A schematic of study reach layout from different starting points are shown in
302 Figure 4, with study reaches highlighted in yellow and an aerial photo with an example of the
303 sample reach layout is shown in Appendix D). The first and last 25 m intervals at the end of the
304 RMZ segment would be excluded from sampling (highlighted in orange in Figure 4). If the full
305 length of the study reach cannot be accommodated before the end of the segment is reached,
306 the remaining portion of the study reach would be continued at the opposite end of the
307 segment on the same side of the stream. While logistically cumbersome, such an approach
308 ensures that all areas along the length of the RMZ segment have an equal probability of being
309 sampled. We proposed using the 100 m long sample unit instead of using multiple smaller plots
310 because of the extra cost and logistical challenges of implementing a multiple plot design.

311
 312 Unharvested areas. Some RMZs include areas where the harvest treatments are not applied
 313 due to other constraints, such as areas that receive no-harvest buffers due to unstable slopes,
 314 wetlands, or tributary junctions, or areas where harvest is not economically or operationally
 315 feasible. If an unharvested area is <25 m in length it will be skipped (not sampled) and the study
 316 reach layout will continue on the far side (Figure 4, bottom row). If the unharvested area is >25
 317 m in length, the study reach starting point will be relocated to a new random start point that
 318 meets the 150 m minimum length criterion for a study reach.
 319

Survey starting point	25 m intervals									
	0–25	25–50	50–75	75–100	100–125	125–150	150–175	175–200	200–225	225–250
25 m	Orange	Yellow	Yellow	Yellow	Yellow	White	White	White	White	Orange
50 m	Orange	White	Yellow	Yellow	Yellow	White	White	White	White	Orange
75 m	Orange	White	White	Yellow	Yellow	Yellow	Yellow	White	White	Orange
100 m	Orange	White	White	White	Yellow	Yellow	Yellow	Yellow	White	Orange
125 m	Orange	White	White	White	White	Yellow	Yellow	Yellow	Yellow	Orange
150 m	Orange	Yellow	White	White	White	White	Yellow	Yellow	Yellow	Orange
175 m	Orange	Yellow	Yellow	White	White	White	White	Yellow	Yellow	Orange
200 m	Orange	Yellow	Yellow	Yellow	White	White	White	White	Yellow	Orange
50 m	Orange	White	Yellow	Yellow	Red	Yellow	Yellow	White	White	Orange

320 Figure 4. Example of layout options for 100 m long study reaches beginning at different possible
 321 starting points within a 250 m long RMZ segment. The study reaches are highlighted in yellow.
 322 The 25 m areas at the edge of the segment that would not be sampled are highlighted in
 323 orange. The bottom row shows an unharvested area within the study reach (highlighted in red)
 324 that would not be sampled.
 325

326 Road crossings. Approximately 2% of the segments in the FPA/GIS analysis had perpendicular
 327 road crossings through the RMZ and over the stream. Segments with perpendicular road
 328 crossings will be disqualified and study reach layout will be handled as described above for
 329 unharvested areas >25 m in length.

330 **Methods**

331 **Layout**

332 Layout will begin by locating the downstream end of each selected RMZ segment. The crew will
333 then walk the segment measuring the length in meters. The starting point of the study reach
334 will be randomly selected and the starting and end points of the survey reach will be
335 monumented with a permanent stake and flagging. The core, inner and outer zone boundaries
336 along the study reach will be delineated using the methods described in McConnell and
337 Heimburg (2010). All boundaries will be documented with a GPS.

338 **Data Collection**

339 **Stand structure**

340 Data will be collected on all standing live and dead trees with diameters ≥ 4 inches at breast
341 height [4.5 ft (1.37 m) above ground] that are within the core or inner zone of the RMZ. Data
342 recorded for each tree include the condition (live or dead), species, diameter at breast height
343 (DBH) and regulatory zone (core or inner). The canopy class (overstory, understory, or open) is
344 recorded for live trees. Data recorded for dead trees includes decay characteristics (Table 5)
345 and mortality agent (e.g. wind, bank erosion, suppression, fire, insects, disease, and physical
346 damage) when it was possible to determine. All stumps within the inner zone boundary will be
347 counted and their diameter and height above ground will be measured.

348 **Fallen trees and large wood recruitment**

349 The RMZ will be surveyed to identify fallen trees that originate from within the core and inner
350 zones of the study reach that recruited to the channel (i.e. a portion crossed the plane of the
351 bankfull channel) during the post-harvest period. Pre- versus post-harvest downed trees will be
352 differentiated using decay data collected on each down tree using the attributes and
353 descriptors in Table 5. The species, DBH, source distance, zone (core or inner), and agent (e.g.,
354 bank erosion, windthrow) that caused the tree to fall will be recorded. Decay class has been
355 successfully used in post-harvest studies to differentiate pre- versus post-harvest riparian stand
356 mortality in Pacific coastal forests (Liquori 2006, Martin and Grotefendt 2007, Bahuguna et al.
357 2010, Schuett-Hames et al. 2012).

358
359 Recruited large wood (LW) includes pieces originate from trees that were growing within the
360 core and inner zone of the study reach. Each piece must be at least 10 cm in diameter (small
361 end of log) and 1 m in length, and a portion of the piece must extend across the plane of the
362 bankfull channel edge, coming to rest either within or above the bankfull channel. Data will be
363 collected on each recruited LW piece, including species, recruitment class, and in-channel
364 functions. Separate lengths and midpoint diameters for the within- and above-bankfull portions

365 will be used to calculate in-channel and over-channel recruited volume (Schuett-Hames et al.
366 1999).

367 Table 5. Decay attributes and descriptors that will be used to define pre- vs. post-harvest
368 mortality from Robinson and Beschta (1990), Washington Dept. of Natural Resources (1996),
369 Martin and Grotefendt (2007), Bahuguna et al. (2010).

Feature	Category
Leaves/needles	Green, Red, Brown, Absent
Bark	Intact, Partial (sloughing), Trace, Absent
Twigs (<3cm)	Present (many); Few-absent
Branches	Secondary branches present, Primary branches only, No branches
Wood texture	Intact, Smooth, Abrasion (some holes and openings), Vesicular (many holes/openings)
Shape	Round, Oval, Irregular
Color	Original (bright), Darkening (inc. gray weathering), Dark

370 **Canopy closure/cover**

371 Canopy closure data will be collected at systematic intervals along the study reach. The first
372 measurement station will be located at the study reach boundary and additional measurements
373 are taken at 25m intervals, with the last station at the far study reach boundary (for a total of
374 five measurements). Two procedures will be used to collect canopy closure measurements at
375 each station using a concave spherical densiometer.

376
377 The first procedure is described in the Forest Practices Board manual for evaluating canopy
378 closure. Measurements will be taken at the center of the stream with the densiometer held one
379 meter above the water surface. Four readings are made at each station viewing a reflected
380 image of the stand in the densiometer facing upstream, downstream, left bank, and right bank,
381 counting the number of points (from a total of 96) with obstructed view to sky (Pleus and
382 Schuett-Hames 1998). Percent canopy closure is calculated for each station by averaging the
383 four readings and multiplying by 1.04 (Strickler 1959).

384
385 The second procedure consists of a single reading taken at the channel edge facing towards the
386 RMZ being sampled (Platts et al. 1987, Mills and Stevenson 1999). This procedure has the
387 advantage of measuring canopy density for the stand being surveyed by eliminating variability
388 from the trees on the other side of the stream and by taking measurements at a consistent
389 distance from the RMZ regardless of stream width. The reading is taken using 17 dots in a
390 wedge-shaped portion of concave spherical densiometer (Strickler 1959; Platts et al. 1987). The
391 percentage canopy closure for each station is calculated by multiplying the total number of

392 obstructed dots by 5.88 and the average will be computed from all stations within the study
393 reach

394 **Soil disturbance**

395 Surface erosion within the core and inner zone, and potential sediment delivery to the stream
396 will be assessed by examining the stream bank and RMZ using methods based on Litschert and
397 MacDonald (2009). Data will be collected on the length, average width, distance to edge of the
398 bankfull channel and channel delivery (yes, no) for each erosion feature. The type of
399 disturbance (e.g. root-pit, yarding, bank erosion, mass wasting) will be noted.

400 **Metrics**

401 Table 6 identifies the metrics that will be used in the analyses and describes how they will be
402 computed. The procedures to calculate tree mortality and trajectory to DFC are described in
403 more detail in the following section.

404 **Tree mortality**

405 The number and basal area of trees that died since harvest will be estimated from the decay
406 class of dead and fallen trees. Annual post-harvest mortality rates will be calculated using the
407 formula in Table 6. To use decay class to estimate mortality, we will create a list of all dead and
408 fallen trees that exhibit recent mortality (that occurred since timber harvest). Recent mortality
409 will be estimated from the relationship between decay attributes and time since mortality for
410 each dead tree. Table 7 shows examples of how decay data and time since mortality
411 relationships have been successfully used in studies of snag mortality and for estimating rates
412 of riparian large wood recruitment (Martin and Benda 2001, Benda et al. 2002, Hennon et al.
413 2002; Liquori 2006, Bahuguna et al. 2010, Schuett-Hames et al. 2012).

414

415 Table 6. Description of methods used to calculate metrics used in the analysis.

Metric	Calculation	Description
Stand structure		
Stem density (post-harvest)	Live stem count divided by acreage (by core and inner zone)	trees/acre
Basal area (post-harvest)	Calculate basal area for each live tree using the formula: $basal\ area\ (ft^2) = 0.005454 * dbh^2\ (inches)$. Sum live tree basal area for each segment and divide by acreage (by core and inner zone).	ft ² /acre
Mortality		
Mortality rate as percent of initial live stem count	Calculated as an annualized rate: $\%count/yr = ([ending\ live\ tree\ count/immediate\ post\ harvest\ live\ tree\ count]^{1/number\ of\ years\ in\ period}) - 1$	%stems/yr
Mortality rate as percent of initial live basal area	Calculated as an annualized rate: $\%basal\ area/yr = ([ending\ live\ tree\ basal\ area/beginning\ live\ tree\ basal\ area]^{1/number\ of\ years\ in\ period}) - 1$	%basal area/yr
Large wood recruitment		
LW recruitment rate by piece count	Calculated as a rate: LW pieces recruited/100m/yr = ([LW pieces/reach length in m]*100)/years in period	pieces/100 m/yr
LW recruitment rate by volume	Calculated as a rate: ([LW volume in m ³ /reach length in m]*100)/years in period	m ³ /100 m/yr
Canopy closure/cover		
Percent canopy closure- 4 directions	Sum the counts of obstructed points for each of the 4 readings at each station. Divide by 4 and multiply by 1.04. Average the station values to calculate the mean for each study reach.	% 4d canopy closure
Percent canopy closure-towards RMZ	Count the number of obstructed points (out of 17 possible) and multiply by 5.88. Average the station values to calculate the mean for each study reach.	% RMZ canopy closure
Soil disturbance		
Erosion surface area	Sum the surface area (m ²) of sediment delivering erosion features, divide by study reach length in m and multiply by 100.	m ² /100 m
Trajectory to DFC		
DFC target performance target	Run DFC worksheet using live tree list for each study reach to determine if basal area meets or exceeds DFC target (325 ft ² /acre at age 140). Calculate the proportion of segments in each strata projected to meet the target. For sites with <325 ft ² , divide projected basal area by 325 to determine percent difference.	Proportion of site projected to meet target % of target DFC

416

417 We recognize that the published relationships for decay class and time since mortality may
 418 need to be calibrated for the species and climate applicable for our study area. Therefore, we
 419 will use tree mortality data from a field survey of marked dead trees in the CMER Type N "soft
 420 rock" study (Ehinger et al., 2011) to establish decay class relationships for species common to
 421 the proposed study area.

422

423

424 Table 7. Examples of published estimates for time since death for snags, down trees, and large
 425 wood recruits by decay class for two Pacific coastal regions.

Category	Description	Mean time since death (yrs)		
		Martin & Benda 2001 conifer, Southeast AK	Benda et al. 2002 conifer, coastal CA	Benda et al. 2002 deciduous, coastal CA
1	Foliage (live/dead leaves and needles) present	--	2.7	1
2	Twigs present	7.6	4.1	4.1
3	Secondary branches present	10.1	5	4.7
4	Primary branches present	18.7	14.3	8.8
5	No branches remaining (nubs may be present)	30.3	24.3	19.3

426
427

428 Analysis

429 The goals of data analyses are to:

- 430 • identify and assess the relative magnitude of differences in riparian stand conditions
- 431 and functions among the prescriptions variants,
- 432 • estimate the proportion of stands that are projected to achieve the DFC performance
- 433 target and erosion performance target,
- 434 • evaluate the post-harvest riparian stand conditions and riparian ecological functions
- 435 across prescription variants, and
- 436 • summarize pilot study results to inform the more intensive BACI follow-up study once
- 437 BACI study objectives and budgets have been finalized.

438

439 The analyses will consist of a combination of approaches including: 1) comparing and
 440 contrasting post-harvest study variables among RMZ treatments using parameter estimates and
 441 associated estimates of uncertainty, and 2) comparing post-harvest conditions to the FPHCP
 442 resource objectives and performance targets. The approach, or combination of approaches, will
 443 vary depending on the question of interest.

444 *Estimating means and confidence intervals for response variables and comparison of* 445 *post-harvest response variables among prescription variants*

446 A mean with confidence intervals, as well as box plots of the observed range of values will be
 447 calculated for each response variable for each prescription variant. The 90% confidence
 448 intervals and distribution of values will be examined to assess the variability in the metrics

449 measured for each prescription variant, and to identify particular instances where unusually
450 large differences occurred.

451

452 We intend for the results to be primarily these estimates, associated confidence intervals,
453 graphical comparisons, pilot data, and the understanding that comes with them. These results
454 will be able to answer questions such as:

- 455 • How variable is large wood recruitment within prescription variants?
- 456 • Do we see that mean large wood recruitment is very different from one prescription
457 variant to another?
- 458 • Which prescription variants have the largest values for large wood recruitment and
459 which the smallest?
- 460 • Can we see any patterns in which differences in mean large wood recruitment or
461 differences in variability of large wood recruitment occur systematically such as
462 between prescription variants with inner zone harvest and without or between
463 prescription variants on large versus small streams or along spatial gradients in where
464 prescriptions exist along the landscape?

465

466 Because there is a general interest in understanding how response to prescription variants
467 might differ across the landscape or in response to specific conditions that we do not have
468 adequate sample size to control for, we may be able to create models. These models are a
469 byproduct of the study and not the main purpose of the study.

470

471 Factors, e.g., covariates, that might be investigated with models include the following:

- 472 • All covariates inherent in the prescription variants such as stream size, site index,
473 harvest in the inner core;
- 474 • Essential ecological factors that may vary by site such as exact stream width (note that
475 only large and small are included above), elevation, aspect, longitude, and latitude;
- 476 • A set of variables to explore wind exposure including aspect (also included above
477 because aspect might also relate to solar energy inputs and potential growth rates),
478 buffer orientation / exposure, and fetch. These three variables will also be combined
479 into a categorical (1–5) ranking of wind exposure (Rollerson et al. 2009).
- 480 • A small set of harvest features that we cannot capture with additional stratification but
481 which we would like to understand better before designing the BACI study. These
482 include presence of harvest on the opposite bank, total length of stream treated,
483 presence/absence of yarding corridors, outer zone harvest strategy.

484

485 Models would generally take the following form. We note that, given sample size constraints,
486 there would likely be at most only one factor and an interaction or two factors with no
487 interaction but the full model form is described for completeness. All models would be
488 exploratory rather than confirmatory. We are looking for patterns that might help us build a
489 better BACI design or that might lead to further testing with additional data. We are not testing
490 hypotheses or attributing causation:

$$491 \quad \text{Response (Table 6)} \sim \text{Prescription} + \text{Factor1} + \text{Factor 2} + \text{Prescription:Factor1} + \\ 492 \quad \text{Prescription:Factor2} + e$$

493
494 Such models might be simple linear models if all factors were fixed and the distribution of the
495 residuals could be assumed to be normal. Such models might be as complicated as generalized
496 linear mixed effects models if one of the factors were considered a random effect and the
497 residuals were likely from a non-normal distribution. Models could be used to quantify
498 differences in response among the prescription variants, to determine whether harvest on the
499 opposite bank, presence of yarding corridors or outer zone harvest strategy needs to be
500 accounted for in the full BACI study, and to estimate where specific responses can be pooled
501 across prescription variants. For example, in an analysis of windthrow mortality it may be
502 possible to combine the Site Class V large and small stream strata (60–66 ft buffers) for a
503 comparison with much wider buffers (e.g. Site Class III small and large stream strata;93–105 ft
504 buffers). In no case would strata with inner zone harvest be combined with strata with no-
505 inner-zone-harvest.

506
507 Spatial autocorrelation between sites may be an issue but we have minimized it to the degree
508 possible. First, we are restricting the sampling design to allow only one study site per USGS HU.
509 This will maximize spatial spread given our stratified random sampling plan. We will also
510 explore whether latitude and longitude describe trends in the data for each response metric. If
511 there are, for example, East-West trends in stand structure after harvest, this will be essential
512 to incorporate in the BACI design and in our descriptive assessment of on-the-ground
513 conditions in this pilot study. Lastly, we will incorporate factors that describe wind exposure.
514 There are three possible variables (aspect, orientation of buffer, and fetch) which can be
515 explored one by one and as a combined 1–5 categorical ranking of wind exposure (Rollerson et
516 al. 2009). Lastly, we can plot residuals from our descriptive models above in space to visually
517 explore whether there is spatial pattern remaining. Spatial covariance would likely lead to
518 confidence intervals on our effects that are slightly smaller than they should be if the data were
519 independent. If we find evidence of residual spatial covariance, we can note this potential
520 impact in our findings.

521 **Comparison with existing performance targets**

522 We will determine the percentage of RMZ segments in each prescription variant grouping that
523 meet or exceed the performance targets for stream bank/equipment limitation zone
524 disturbance and the DFC target for riparian condition in Appendix N of the FPHCP.

525
526 Erosion data from each segment will be compared used to determine the percentage of
527 segments in each prescription variant that meet the stream bank/equipment limitation zone
528 disturbance target of no stream bank disturbance outside of road crossings.

529
530 The DFC worksheet (<https://fortress.wa.gov/dnr/protection/dfc/DfcRun.aspx>) uses stand
531 inventory data in conjunction with a stand growth model to project basal area per acre in the
532 combined core and inner zone at a stand age of 140 years. We will run the DFC worksheet with
533 stand data from each RMZ segment to predict basal area at age 140 for each segment. The
534 results will be used to: 1) estimate the change in projected trajectory for each site, 2)
535 determine if the site meets the target of 325 sq ft of basal area at 140 years, and the percent
536 deviation above or below the target, and 3) estimate percentage of sites on target for each
537 prescription variant.

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608 **Appendix A. Forest Practice Application-Geographic Information System** 609 **(FPA-GIS) Analysis**

610 **Purpose**

611 This document describes an office review and analysis of forest practice applications (FPAs) to supply
612 information to inform the design of the Western Washington Type F Prescription Monitoring Project
613 pilot study. The purpose of this analysis is to determine how frequently different variations of the
614 western Washington prescriptions for Type F (fish-bearing) and Type S (shorelines of the state) riparian
615 management zones (RMZs) are being implemented, regional distribution patterns, and provide
616 information on the characteristics of sites where the prescriptions are being applied.

617 **Methods**

618 Data were collected on Type F and S stream segments in harvest units contained in a random sample of
619 Forest Practices Applications (FPAs) selected from the Washington Department of Natural Resources
620 (WDNR) Forest Practices Application Review System (FPARS) database. The information used in this
621 process came from:

- 622 1. archived PDFs in the DNRs Forest Practice Application Review System (FPARS)
623 <https://fortress.wa.gov/dnr/protection/fparssearch/>, and
- 624 2. DNRs FPARs Geographic Information System (GIS) database <http://www.dnr.wa.gov/GIS>

625 To be included in the survey, each FPA had to meet the following criteria:

- 626 • timber harvest along a Type F water within the area of the proposed FPA (this criterion excludes
627 FPA's where harvest is restricted to salvage or road right-of-ways)
- 628 • harvest under the "standard" westside Type F forest practices rules (this criterion excludes
629 Alternate Plans, Habitat Conservation Plans, conversions to other land uses, 20 acre exempt
630 parcels, and hardwood conversions)
- 631 • an effective date between 2008 and 2013
- 632 • within the Northwest, Olympic, Pacific Cascade, or South Puget Sound DNR regions

633 **Sample selection and data collection procedures**

634 The process used to screen FPAs included four steps:

635 **Step 1. Select potential FPAR data for analysis**

636 Download the FPARs data (GIS unit boundary shapefile and associated attribute table) and select those
637 FPA/units with the desired characteristics.

638 EFFECTIVE_DT (Effective date): select for dates between July 1, 2008 and June 30, 2013 (dates likely to
639 have been harvested within our harvest window (June 2011-July 2013)).

640 REGION_NM (DNR region): select for Northwest, Olympic, Pacific-Cascade or South Puget Sound
641 (excludes eastside regions).

642 DECISION (Status of Application): select for APPROVED or RENEWAL (excludes applications that are not
643 approved for harvest).

644 ALTERNATE_PLAN_FLG (Alternative Plan Submitted): exclude Y (excludes activities conducted under an
645 alternative plan).

646 HABITAT_CONSERVATION_FLG (Application covered by Habitat Conservation Plan): select for blanks-
647 (excludes activities conducted under a Habitat Conservation Plan).

648 CUTTING_OR_REMOVING_TIMBER_FLG (Involves cutting or removing timber): select for Y (excludes
649 FPAs without timber harvest, e.g. road construction, chemical application).

650 EXEMPT_20_ACRE_RMZ_FLG (Application qualifies for less than 20 acre parcel RMZ prescription):
651 exclude Y (excludes FPAs with RMZ harvest under special 20 acre parcel exemption).

652 HARDWOOD_CONVERSION_FLG (Hardwood conversion applications): exclude Y (excludes hardwood
653 conversion applications).

654 TIMHARV_FP_TY_LABEL_NM (harvest type): select for EVEN AGE, UNEVEN AGE, EVEN/SALVAGE,
655 UN/SALVAGE, EVEN R/W, UNEVEN R/W (excludes FPAs limited to right-of-way, salvage, or no harvest).

656 CMZ_PRESENT_FLG (channel migration zone): exclude Y (excludes RMZs with channel migration zone
657 buffer present)

658 **Step 2. Identify FPAs within 200 ft of a Type F or S stream.**

659 Using WDNR statewide hydrography (downloaded 16 January 2016 from www.dnr.wa.gov/GIS), restrict
660 the hydro layer to F and S segments and use the ArcGIS Near function to identify those FPAs from Step 1
661 that are within 200 ft of a Type F or S stream.

662 **Step 3. Put list of selected potential FPARs units in random order.**

663 Use an ArcGIS script to assign a random integer between 1 and 1000000 to each FPA, sort on
664 the random number, and work systematically through the sorted list.

665 **Step 4. Screen the FPAs in assigned order to verify there is a Type F or S stream in or adjacent to the 666 harvest unit.**

667 Working thru the randomized list of FPA numbers from the top, ArcGIS was used to overlay the FPARs
668 unit boundary polygon on the 2013 NAIP imagery and the WDNR hydrography to verify that there was a
669 Type S or F stream in the unit and to determine if the unit was harvested prior to 2013. If no type F or S
670 stream was present in the unit the FPA was rejected. The data were manually screened to remove
671 duplicate records, or FPAs with HCPs or Alternative Plans that were missed in Step 1.

672 **Step 5. Collect data on attributes of interest for each of the selected FPAs.**

673 Using the FPARs database, the pdf file for each FPA, the FPARs unit boundary polygons, and other GIS
674 information (hydro layer, NAIP imagery, DEM, SSHAIP) extract and record the data on each Type F or S
675 stream segments identified in each FPA. Table 1 (next page) shows the data attributes and provides a
676 brief description of the procedures to obtain the information.

Table 1. FPA-GIS analysis data attributes and procedures.

Field	Description	Source	Procedures
FPA Number	FP_ID, unique identifier for each FPA.	FPARs database	Copy data field in FPARs database
DNR region	REGION_NM, DNR region	FPARs database	Copy data field in FPARs database
Landowner Name	Name of legal landowner	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
Project name	Landowner name of project/unit	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
County	County FPA is located in	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
WAU	WAU FPA is located in	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
WRIA	WRIA FPA is located in	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
Harvest Type	Type of harvest (even, uneven age, salvage)	FPA pdf	Copy data field in FPARs database
Effective Date	EFFECTIVE_DT, month/day/yr activities may begin.	FPARs database	Copy data field in FPARs database
Harvested by 2013?	Unit harvested on 2013 NAIP photography	2013 NAIP imagery	Overlay FPAR harvest unit polygon with 2013 NAIP imagery
Stream segment	Individual Type F segment identifier	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
Water type	Water Type classification	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
site class	DNR site class	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
stream width	Average stream width	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
stream width cat	Greater than or less than 10 ft	Table 21 in FPA pdf file	Calculate based on stream width in FPA table
Inner zone harvest	Yes or No, If yes, record code for inner zone harvest	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
Outer zone harvest	Yes or No, If yes, record code for outer zone harvest	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
CMZ present	Channel migration zone present	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
Total RMZ width	Width of total RMZ (core+inner+outer)	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
DFC worksheet?	Yes if DFC worksheet included in FPA	DFC worksheets in FPA pdf.	Look for DFC worksheet in FPA (RMZ harvest codes D ore E)
Usable FPA map	Yes if activity map in FPA is legible and identifies location of stream segments in table	map in FPA pdf.	Examine FPA map provides useful information
RMZ length	Length of stream segment	DFC worksheet or NAIP	In DFC worksheet when present, otherwise GIS stream layer
1 or 2 sided RMZ	Harvest proposed on 1 or both sides of Type F stream?	FPA map, NAIP imagery	Examine FPA map and NAIP imagery
Stream Adjacent Road	Stream adjacent road present in RMZ	FPA Table 21, map, NAIP	Examine FPA map, NAIP imagery, RMZ harvest code G
Road stream crossing	Road stream crossing present in RMZ	FPA Table 21, map, NAIP	Examine FPA map, NAIP imagery, RMZ harvest code H
Yarding corridors	Yarding corridors present in RMZ	FPA Table 21, map, NAIP	Examine FPA map, NAIP imagery, RMZ harvest code J
Elevation	elevation of stream segment (lower, mid, upper)?	GIS-DEM	Extract from DEM
Gradient	channel gradient	GIS- SSHIAP	Extract from SSSIAP
Confinement	channel confinement	GIS- SSSIAP	Extract from SSSIAP
Basin Area	drainage area above segment	GIS-DEM	Calculate from DEM
Aspect	Stream aspect thru segment in downstream direction	GIS-NAIP imagery	Snap line from upper to lower segment boundary

Results

A total of 170 FPAs with harvest adjacent Type F and S streams were included in the analysis. These FPAs included 590 unique stream segments (an average of 3.5 per FPA) which varied in their classification by site class, stream width category, and the harvest option applied. The following results are based on analysis at the stream segment scale.

Geographic distribution

The western Washington Type F prescriptions are applied in four WDNR administrative regions. Half of the segments were located in the Pacific Cascade Region, which includes the Willapa Hills and the southwest slopes of the Cascade Range. Another 35% were in the Olympic Region, which includes the Olympic Peninsula outside of Olympic National Park. The remaining 15% occurred in the South Puget Sound and Northwest Regions (Table 2).

Table 2. Distribution of Type F and S stream segments by WDNR administrative region.

WDNR region	Count	Percent
Northwest	28	4.7%
Olympic	205	34.7%
Pacific-Cascade	295	50.0%
South Puget Sound	62	10.5%

Eighteen western Washington counties were represented in the sample (Table 3). Three counties, Grays Harbor, Pacific and Jefferson, accounted for 60% of the stream segments.

Table 3. Distribution of Type F and S stream segments by WDNR administrative region.

County	Count	Percent
Clallam	42	7.1%
Clark	2	0.3%
Cowlitz	31	5.3%
Grays Harbor	137	23.2%
Jefferson	105	17.8%
King	25	4.2%
Kitsap	2	0.3%
Lewis	30	5.1%
Mason	8	1.4%
Pacific	108	18.3%
Pierce	17	2.9%
San Juan	4	0.7%
Skagit	1	0.2%
Skamania	18	3.1%
Snohomish	14	2.4%
Thurston	21	3.6%
Wahkiakum	18	3.1%
Whatcom	7	1.2%

RMZ harvest options

The vast majority of the stream segments (92.9%) were on streams classified as Type F waters (fish-bearing). The remaining 7% were classified as Type S (shorelines of the state, also fish bearing). The same RMZ requirements apply to both classifications.

Prescription variants

The combination of site class and stream width determines the leave tree and RMZ width requirements in the Type F and S riparian prescriptions, so we examined the distribution of stream segments by both factors. Site class is typically determined from maps provided by WDNR, while stream width is determined from field measurements as described in the Forest Practices Board Manual.

Site class

Site class III (57%) and Site Class II (26%) together accounted for over 80% of the stream segments (Table 4). Site Classes I, IV and V each accounted for <10% of the segments, and only 17% when combined.

Table 4. Distribution of stream segments by site class.

Site class	Count	Percent
I	32	5.4%
II	152	25.8%
III	336	56.9%
IV	21	3.6%
V	49	8.3%

Stream width

Both the greater than 10 ft (large stream) and less than 10 ft (small stream) width categories were well represented in the sample, with a higher proportion classified as small streams (58%).

Table 5. Distribution of stream segments by stream width category.

Stream width category	Count	Percent
Greater than 10 ft	248	42.0%
Less than 10 ft	342	58.0%

Since site classes II and III comprised such a large proportion of the stream segments, it is not surprising that the site class III small and large stream categories had the greatest number of stream segments (37% and 20%, respectively), followed by the site class II large and small stream categories (both 13%). The remaining categories had ≤5% of the stream segments (Table 6).

Table 6. Distribution of stream segments by combined site class/stream width category.

Combined site class and stream width category	Count	Percent
Site Class I- large stream >10 ft	19	3.2%
Site Class I- small stream <10 ft	13	2.2%
Site Class II- large stream >10 ft	76	12.9%
Site Class II- small stream <10 ft	76	12.9%
Site Class III- large stream >10 ft	119	20.2%
Site Class III- small stream <10 ft	217	36.8%
Site Class IV- large stream >10 ft	15	2.5%
Site Class IV- small stream <10 ft	6	1.0%
Site Class V- large stream >10 ft	19	3.2%
Site Class V- small stream <10 ft	30	5.1%

The western Washington Type F and S riparian prescriptions regulate harvest in RMZs. If stocking is not adequate to meet the DFC performance target, no harvest is allowed in the inner zone. When stocking is adequate, landowners can use harvest Option 1 (thin from below) in any site class/stream width category. Option 2 (leave trees closest to the water) is allowed in Site Class I or II and the small stream category of

Site Class III. Two thirds of stream segments had no inner zone harvest (Table 7). Option 2 was done in 25% of the segments and Option 1 occurred less than 7% of the time, although it is the only option for removing timber in 5 of 10 site class/stream width categories. DFC worksheets are required for segments where inner zone harvest is proposed, so this information was available for about 30% of the stream segments.

Table 7. Distribution of stream segments by harvest option.

Harvest option	Count	Percent
No inner zone harvest	399	67.6%
Option 1- Thin from below	39	6.6%
Option 2- Leave Trees Closest to the Water (LTCW)	150	25.4%
Yarding corridor only	2	0.3%

Since the harvest characteristics (buffer width, leave tree requirements, and harvest configuration) will vary by site class, stream width category and harvest option, the distribution of stream segments in this framework of 25 potential categories (prescription variants) provides an indication of the likely distribution of the population of stream segments that could be sampled in the pilot study (Table 8).

Table 8. Distribution of stream segments by prescription variant.

Site class	Stream width category	Harvest option	Count**	Percent
I	large stream	No harvest	8	1.4%
I	large stream	Option 1	0	0.0%
I	large stream	Option 2	11	1.9%
I	small stream	No harvest	6	1.0%
I	small stream	Option 1	0	0.0%
I	small stream	Option 2	7	1.2%
II	large stream	No harvest	52	8.9%
II	large stream	Option 1	0	0.0%
II	large stream	Option 2	24	4.1%
II	small stream	No harvest	63	10.7%
II	small stream	Option 1	0	0.0%
II	small stream	Option 2	13	2.2%
III	large stream	No harvest	85	14.5%
III	large stream	Option 1	31	5.3%
III	small stream	No harvest	115	19.6%
III	small stream	Option 1	8	1.4%
III	small stream	Option 2	94	16.0%
IV	large stream	No harvest	15	2.6%
IV	large stream	Option 1	0	0.0%
IV	small stream	No harvest	6	1.0%
IV	small stream	Option 1	0	0.0%
V	large stream	No harvest	19	3.2%
V	large stream	Option 1	0	0.0%
V	small stream	No harvest	30	5.1%
V	small stream	Option 1	0	0.0%

* Opt 2 not allowed in SCIV, SCV, or SCIII>10ft

**1 segment listing an option 2 harvest on a SCIII >10 ft segment was not included, nor were 2 segments with yarding corridors only.

Together, five of the 25 prescription variants contained over 70% of the stream segments. Not surprisingly, three were from SC III and the other two were from SC II. The three SCIII variants included the small stream, no harvest option (20%), small stream, Option 2 (16%) and the large stream, no harvest option (14.5%). The

two SCII categories included the small stream, no harvest option (11%) and the large stream, no harvest option (9%). Twelve other prescription variants had from 1 to 5 % of the stream segments each, and together comprised about 30% of the segments. The remaining eight prescription variants each had no stream segments in the sample. All eight were harvest option 1, thin from below, indicating that thin from below was not typically used, even when it is the only harvest method available to remove timber from the inner zone. These findings are also consistent with the CMER Desktop Analysis Report (McConnell 2007) results indicating that when given the choice, landowners choose Option 2 the vast majority of the time, or choose not to harvest under Option 1 based on leave tree and other stand requirements.

Other factors affecting RMZ harvest

Several other factors affect RMZ layout and stand conditions.

Road crossings

Perpendicular road crossings occurred in about 2% of the stream segments. In these cases, the RMZs were divided by a road right-of-way and crossing structure.

Stream-adjacent roads

In other cases, roads run parallel to the stream (stream-adjacent roads), occupy portions of the RMZ along the length of the stream. In these cases, special prescriptions are applied to compensate for trees harvested during construction of the road right-of-way. Stream-adjacent roads occurred in about 2% of the stream segments sampled, indicating that they are not widespread.

Channel migration zones

A special situation occurs when there is a channel migration zone (CMZ) between the stream and the RMZ. No harvest is allowed within the CMZ boundary, so in effect the width of no-harvest buffer is increased by the width of the CMZ, which can vary greatly. CMZs occurred in only 2% of the stream segments sampled.

Yarding corridors

Yarding corridors are cleared strips running through the RMZ that allow logs to be transported across the RMZ. Yarding corridors were proposed for 2% of the stream segments sampled.

One- and two-sided harvest

In some cases, larger Type F streams are used as the boundary between units, so the harvest (and buffer) is applied to only one side of the stream, while in other cases harvest (with a buffer) occurs on both sides of the stream. The FPA does not explicitly identify whether harvest (and hence the buffer) is applied on one or both sides of the stream, so we examined the harvest unit maps for a subset of stream segments (346) to determine the proportion of one- and two-sided harvests.

In total, about 30% of the stream segment had two-sided harvest. The proportion of segments with two sided harvest ranged from 8-50% among site class-stream width groupings. Two-sided harvest occurred somewhat more frequently in small streams than for large streams in the same site class category.

Table 9. Proportion of stream segments with one- and two-sided harvest by site class and stream width.

Stream width category	Site class	Segment count	1 sided harvest count	2 sided harvest count	% of two-sided harvest
large	I	12	11	1	8.3%
large	II	52	37	15	28.8%
large	III	72	60	12	16.7%
large	IV	6	5	1	16.7%
large	V	9	6	3	33.3%
small	I	9	8	1	11.1%
small	II	40	25	15	37.5%
small	III	132	84	48	36.4%
small	IV	4	3	1	25.0%
small	V	10	5	5	50.0%
All combined		346	244	102	29.5%

Outer zone harvest

In the outer zone, the outermost portion of the RMZ, landowners have the option of clumping or dispersing required leave trees. The dispersal option was most common, selected in 65% of the stream segments, followed by clumping (17%) and mixed dispersal/clumping (16%).

Physical site characteristics.

A limited amount of information was collected on the physical stream characteristics and the setting in which they occurred, using available GIS data.

Channel gradient and confinement

Information on channel gradient and confinement was obtained from the Salmon and Steelhead Inventory and Assessment (SSHIAP) database at the Northwest Indian Fisheries Commission for a subset of sites (210) located within the SSHIAP project area (Water Resource Inventory Areas (WRIAs) 1-23.

Channel gradient varied greatly, with stream segments occurring in all channel gradient categories (Table 10). The greatest proportion of stream segments occurred in the 4-8% category (26%), followed by the <1% category (22%) and the 8-20% category (19%).

Table 10. Distribution of stream segment by channel gradient category.

Channel gradient category	Count	Percent
<1%	46	21.9%
1-2%	16	7.6%
2-4%	27	12.9%
4-8%	55	26.2%
8-20%	40	19.0%
>20%	26	12.4%

The majority of stream segments were classified as confined (69%), followed by unconfined (19%), and moderately confined (12%) (Table 11).

Table 11. Distribution of stream segment by channel gradient category.

Channel confinement category	Count	Percent
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Confined	144	68.6%
Moderately Confined	26	12.4%
Unconfined	40	19.0%

The overall distribution of stream segments according to the gradient/confinement categories used in Washington's Watershed Analysis Process (Table 12) indicates that segments with confined channels occurred most frequently in higher gradient reaches (>2%), while Unconfined and moderately confined segments occurred more frequently in lower gradient reaches (<2%).

Table 12. Distribution of stream segments by channel gradient/confinement category.

Channel gradient-confinement category	Count	Percent
<1%, Confined	3	1.4%
<1%, Moderately Confined	10	4.8%
<1%, Unconfined	33	15.7%
1-2%, Confined	4	1.9%
1-2%, Moderately Confined	6	2.9%
1-2%, Unconfined	6	2.9%
2-4%, Confined	18	8.6%
2-4%, Moderately Confined	8	3.8%
2-4%, Unconfined	1	0.5%
4-8%, Confined	53	25.2%
4-8%, Moderately Confined	2	1.0%
4-8%, Unconfined	0	0.0%
8-20%, Confined	40	19.0%
8-20%, Moderately Confined	0	0.0%
8-20%, Unconfined	0	0.0%
>20%, Confined	26	12.4%
>20%, Moderately Confined	0	0.0%
>20%, Unconfined	0	0.0%

Basin area

Basin area upstream of the upper end of the segment was calculated using a routed digital elevation model (DEM). Basin area varied by 5 orders of magnitude (Table 13), however the majority of stream segments (83%) were between 1 and 100 acres in size.

Table 13. Distribution of stream segments by basin area.

Basin area	Count	Percent
< 1 acre	44	9.8%
1-10 acres	138	30.7%
10-100 acres	193	42.9%
100-1,000 acres	62	13.8%
1,000-10,000 acres	12	2.7%
> 10,000 acres	1	0.2%

Stream aspect

Distribution of stream segments by aspect category (measured on a line from the upstream to downstream unit boundary) was somewhat uniform among the eight categories, ranging from 9%-17%, with the highest proportions in the south, southwest and west categories.

Table 14. Distribution of stream segments by stream aspect.

Aspect Category	Count	Percent
N	53	11.4%
NE	47	10.1%
E	42	9.1%
SE	52	11.2%
S	80	17.2%
SW	71	15.3%
W	70	15.1%
NW	49	10.6%

Appendix B. Statistical “Power” Analysis for Exploratory Pilot Study

As in any pilot study, sample sizes are not as high as might be ideal. Never-the-less, it is important to consider how well the study design will perform using pilot data. Although we are not focusing on statistical testing, we call this a “power” analysis in that it explores the value of our data collection efforts in creating the information we need.

In the pilot study, we are not trying to detect a causal relationship but rather to get estimates of on-the-ground conditions and to assess whether and to what degree these conditions differ across prescription variants.

Using data from non-fish-bearing streams in western Washington that were harvested with 50 ft no-cut buffers from the Westside Type N Buffer Characteristics, Integrity and Function study, we conducted a simulation-based “power analysis” to explore two things.

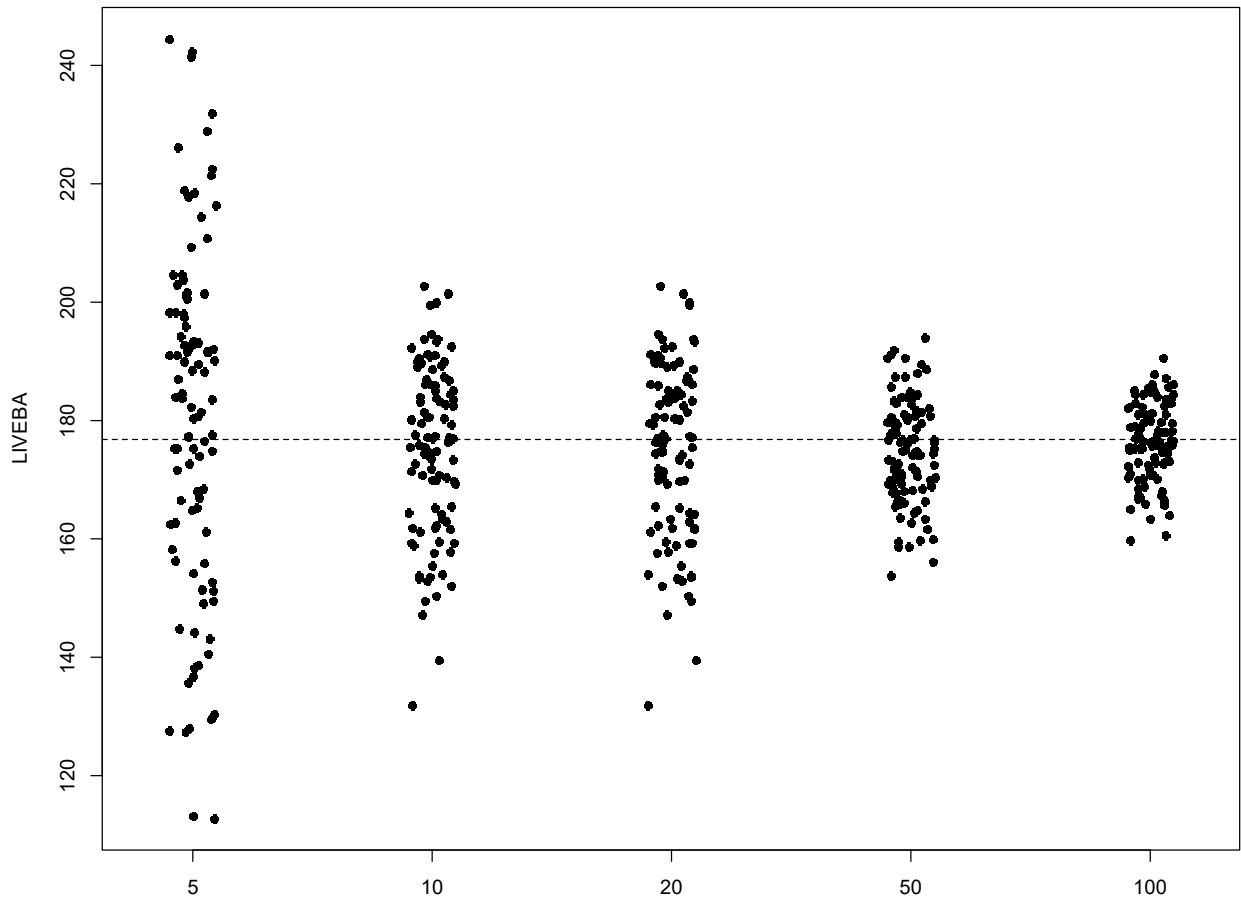
First, we explored how much our estimates of the mean might vary for sample sizes of 5, 10, 20, 50, and 100. We know that we will take just one sample of a particular size, proposed size = 10. It is therefore useful to see how frequently samples of this size have a mean that is far from the truth (estimated by the dashed horizontal line). It is also useful to see how samples of other sizes might compare. These analyses were conducted using a simple Monte Carlo analysis with 100 draws (with replacement) of each sample size from the pilot data.

Second, we explored how the standard error of the mean varied by sample size. This was also conducted using a Monte Carlo simulation. The standard errors of the mean depicted here are the average standard errors over 100 simulations. These should be very close to what would be calculated through simple formulas for variables that are distributed normally but not all responses in the pilot data were distributed normally. Error bars describe a 90% confidence around the estimated mean.

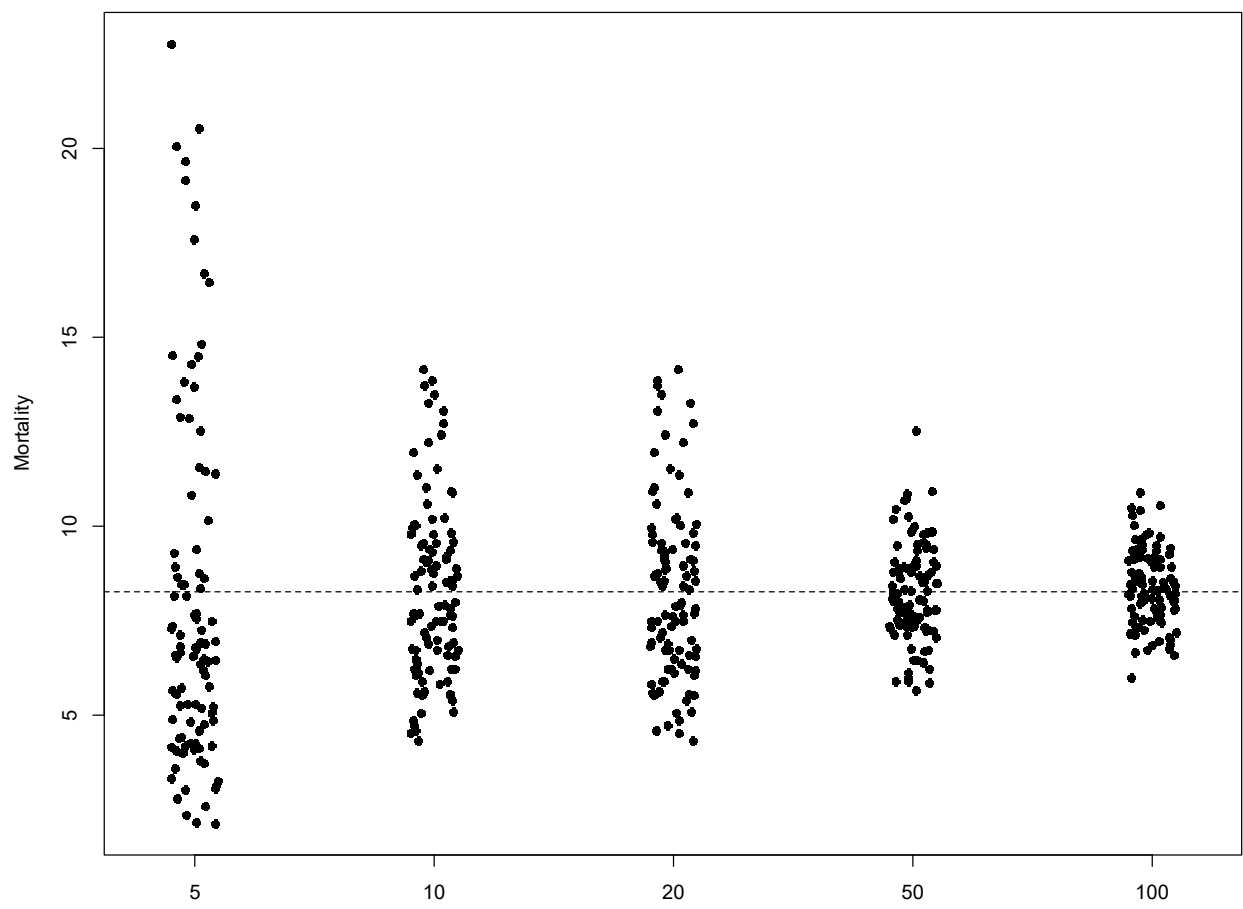
There are limitations to these analyses in that we don’t know whether treated data might have altered variance structures; a sample of size $n=100$ drawn with replacement from a sample of size $n=27$ likely has somewhat reduced variability as compared to a true sample of size $n=96$; and, data are pooled from treated and untreated areas which may provide an increased estimate of variance. As well, there is no guarantee that the data we observe in this study will be similar in terms of distribution as these test data. However, as a general indication of how results may look with our proposed sample size of 10 sites per strata, these analyses are valuable.

The overall conclusions from this exploration is that we will have a reasonable estimate of the mean with a sample of size 10. Smaller samples fairly frequently yield estimates that are far from the truth. Samples that are even twice as big ($n=20$) are fairly similar in the frequency with which sample means are inaccurate. The se of the mean, of course, goes down in proportion to the square root of n for all variables. The projected 90% confidence interval seems reasonable for a pilot study in all cases.

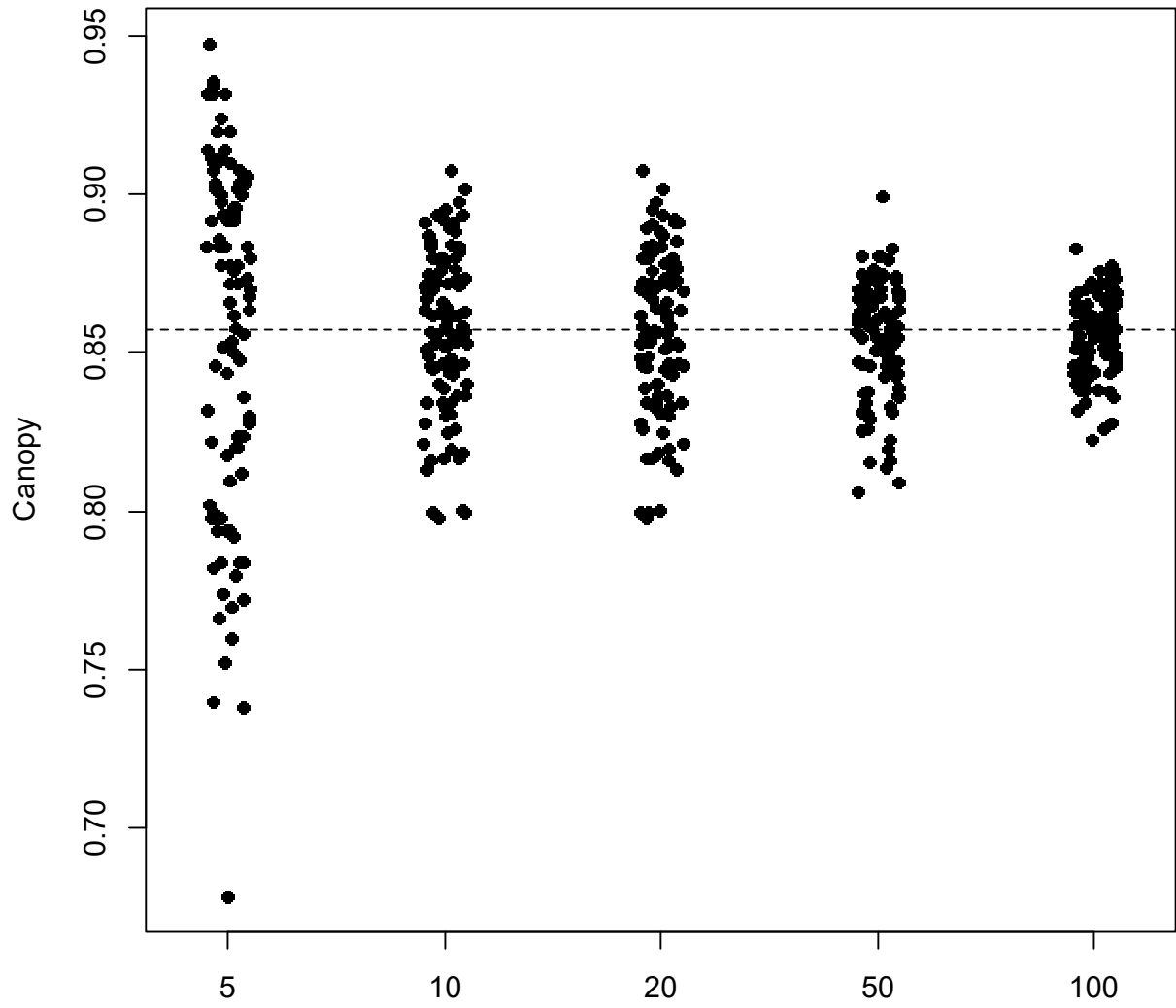
Exploring sample means



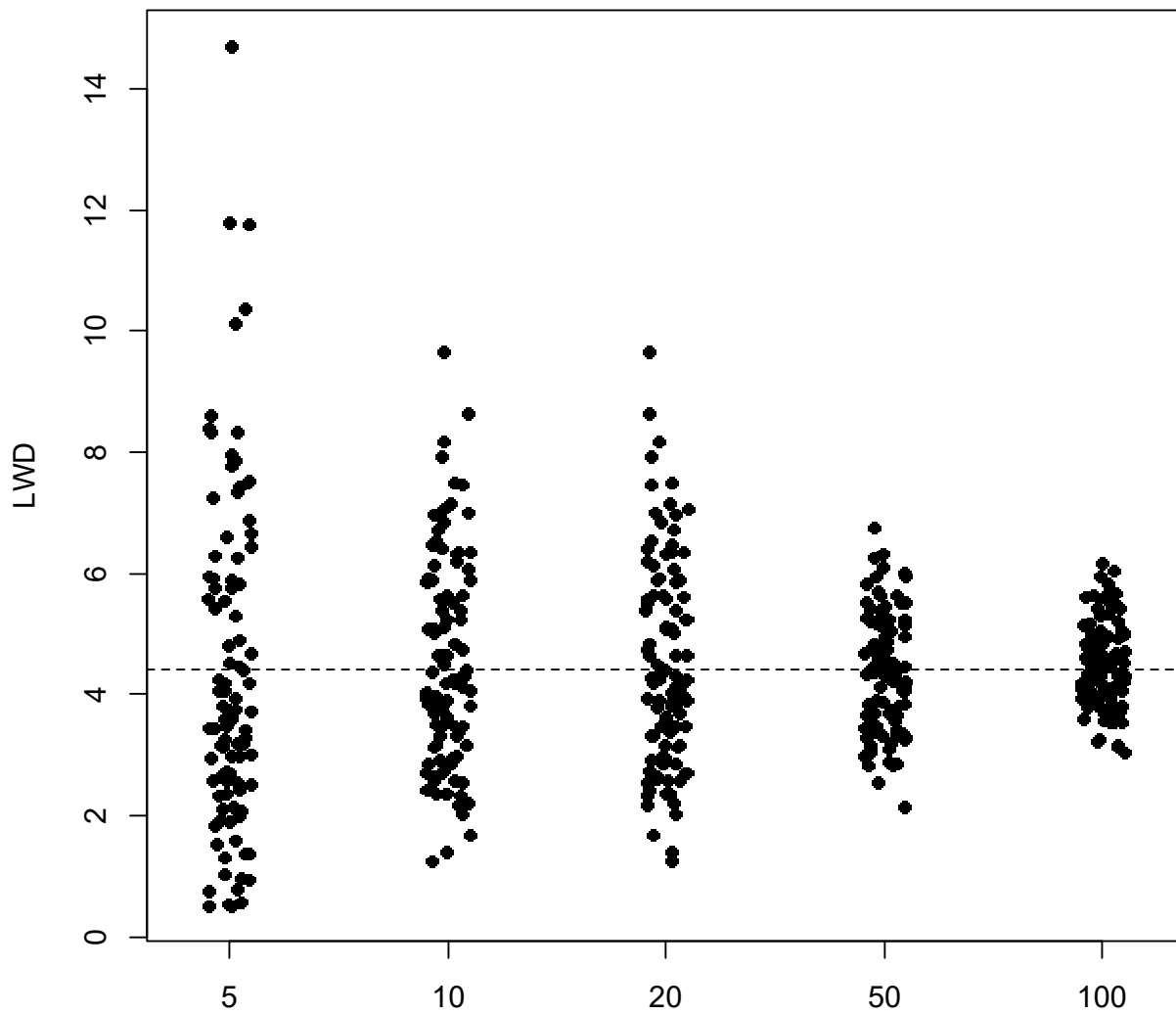
Exploring sample means



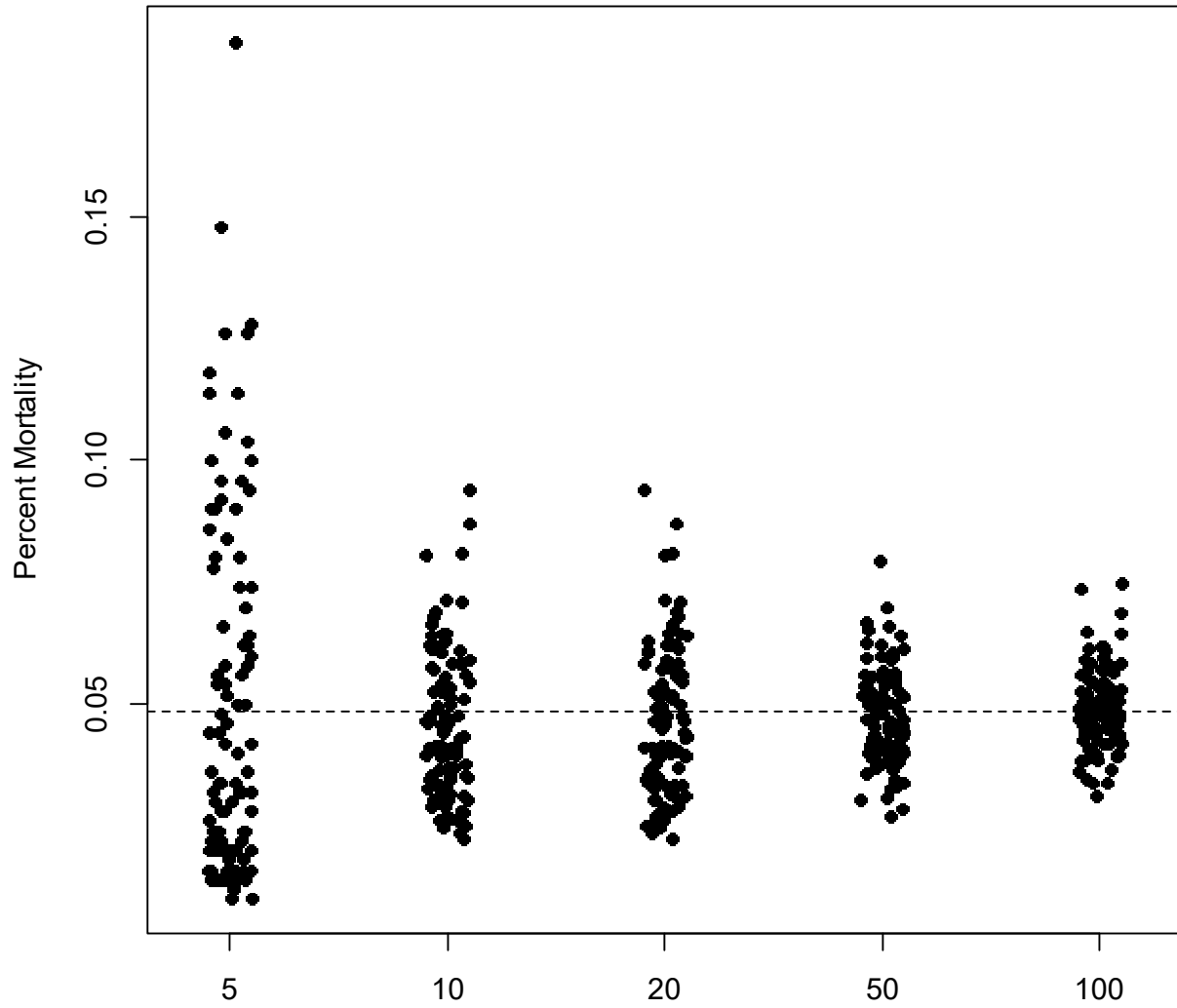
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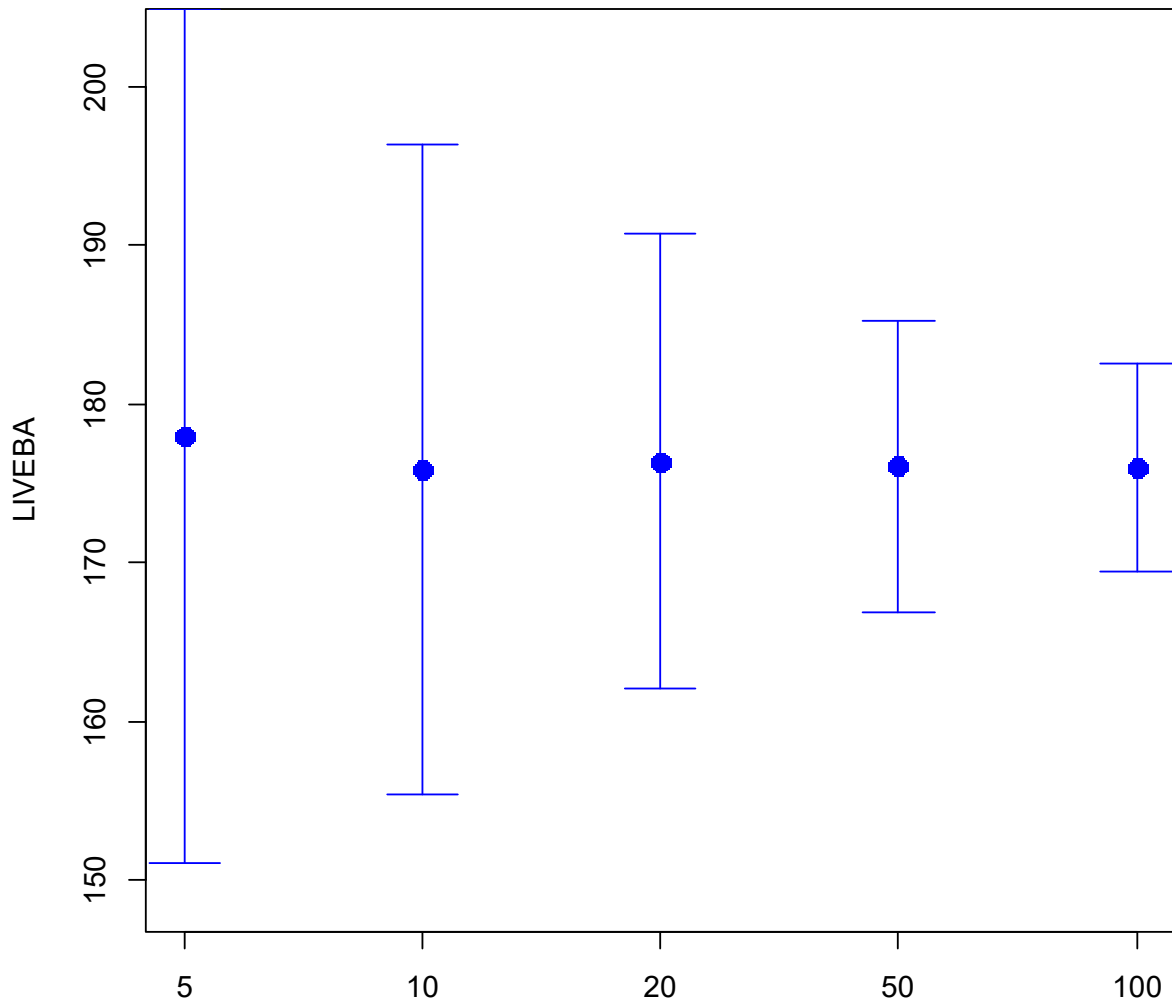
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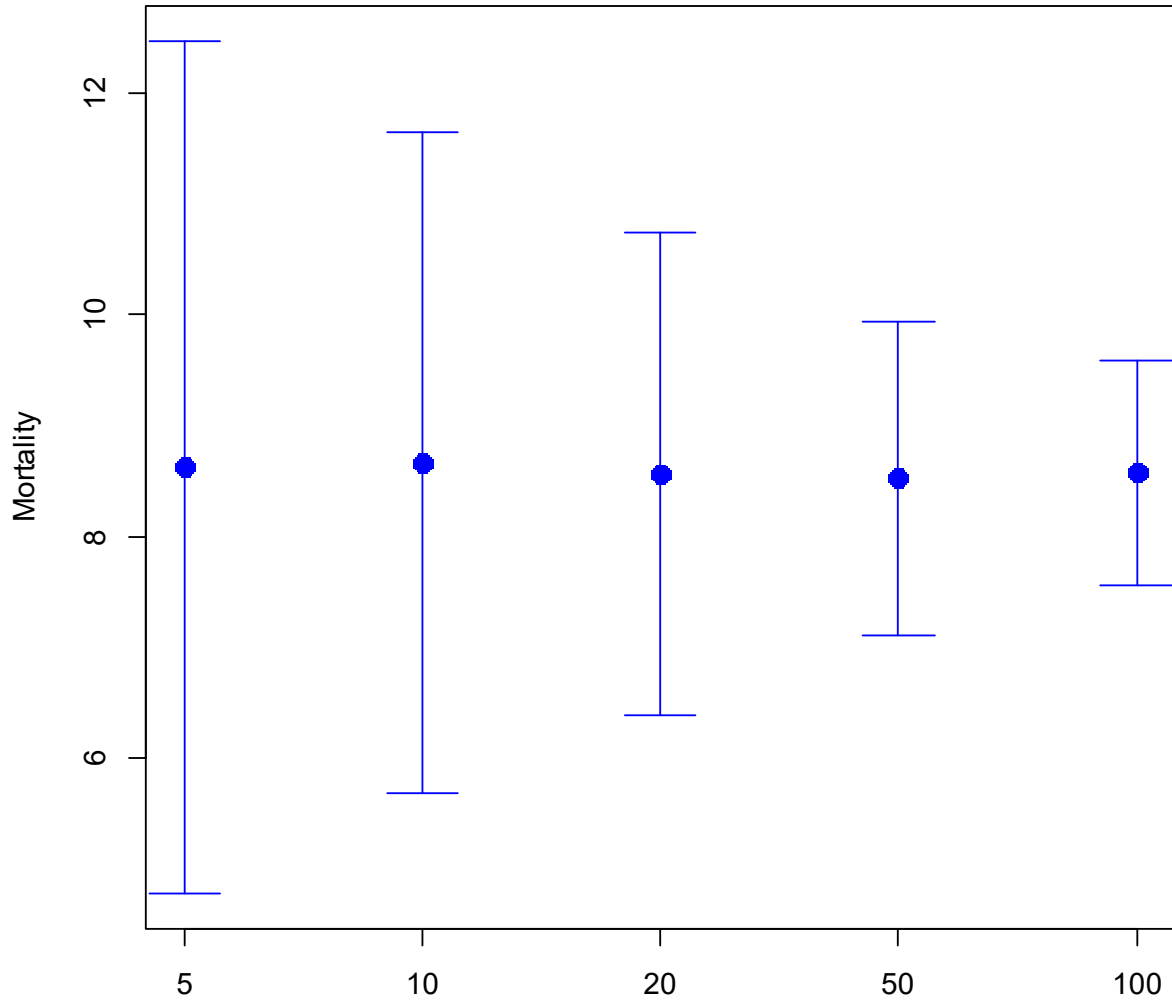
Exploring sample means



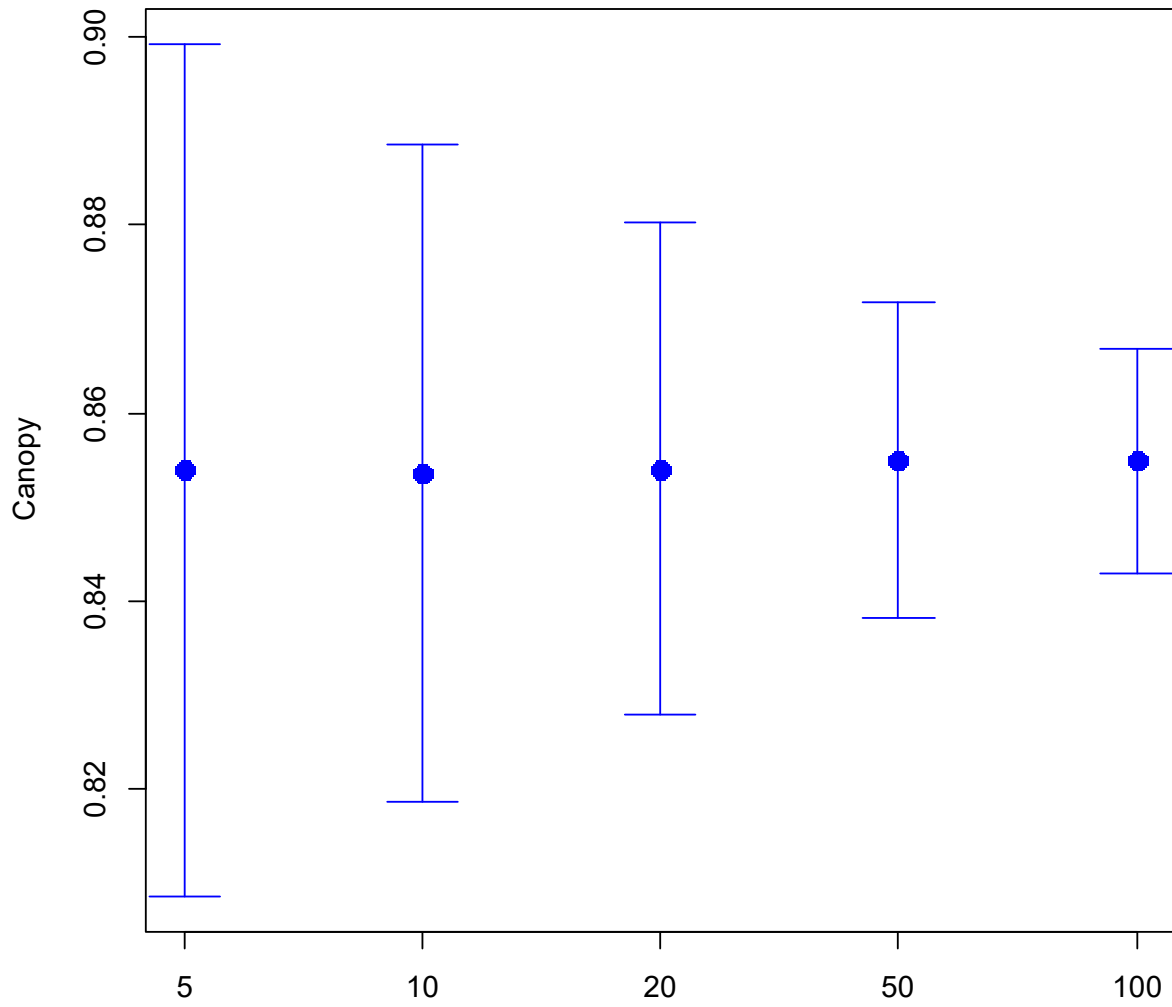
Estimate of the Mean by Sample Size



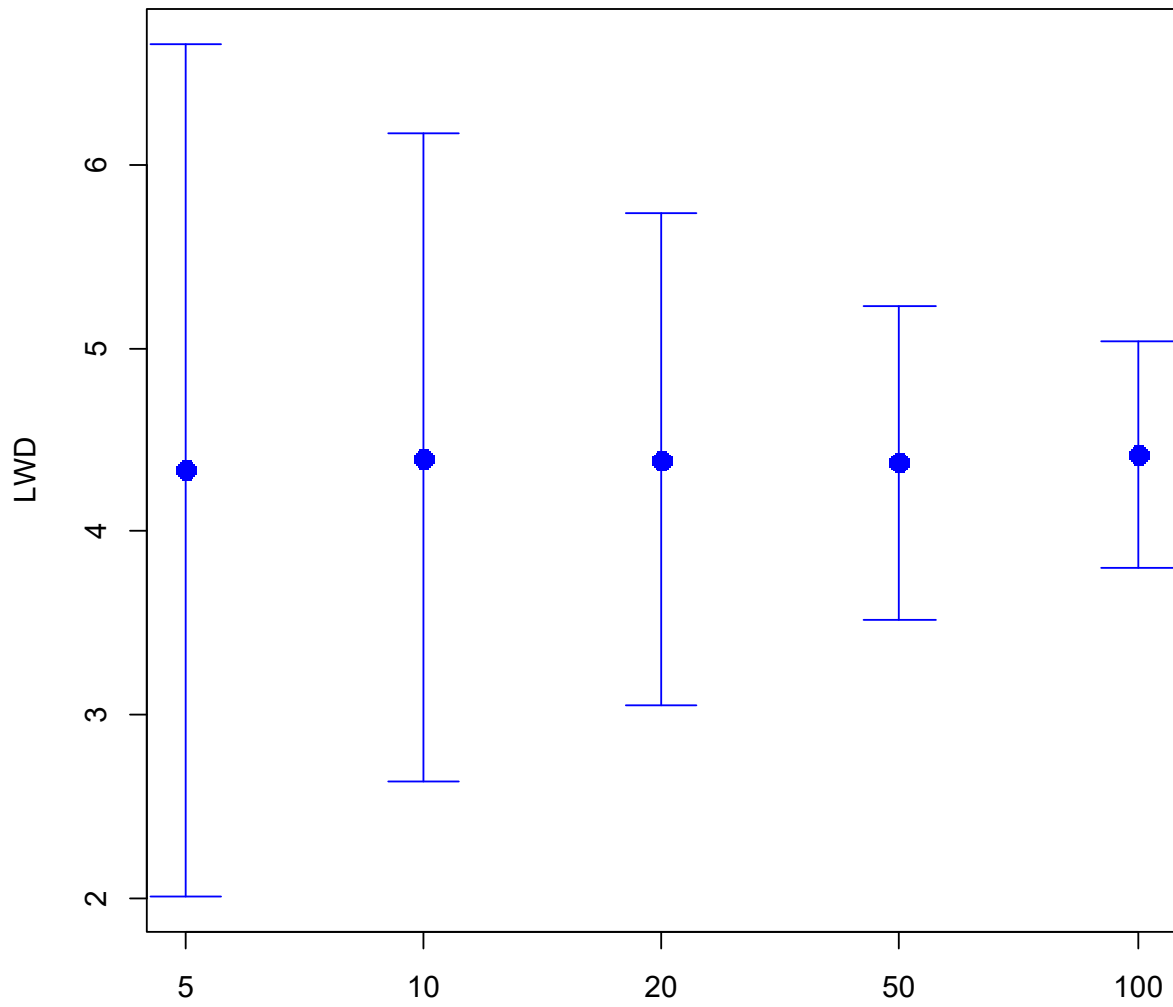
Estimate of the Mean by Sample Size



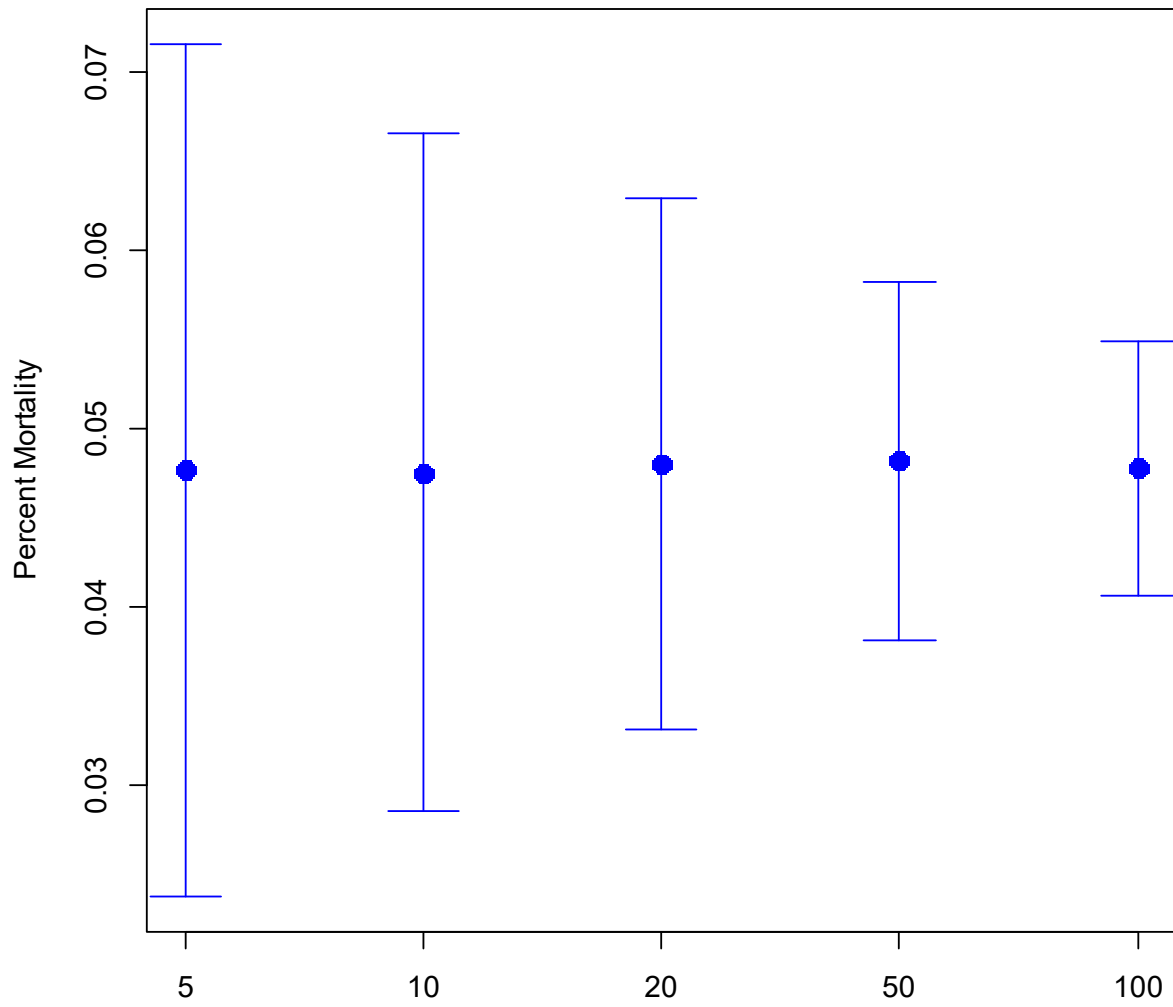
Estimate of the Mean by Sample Size



Estimate of the Mean by Sample Size



Estimate of the Mean by Sample Size



Appendix C. Site Selection Procedure

Following is a detailed description of the site selection procedures.

Materials

- FPARs GIS layer with FPA polygons and associated attribute table
- pdf files for each FPA
- 2015 NAIP photography in GIS format (collected between Aug. 1 and Sept. 15)
- GIS layers for WDNR hydrography and site class
- GIS layer for USGS Hydrologic Unit Maps

The process used to select stream segments include the following steps:

Step 1. Initial screening to select potential FPAs for further evaluation

1. Download FPARs GIS data from the on-line DNR FPARs website, i.e. the GIS unit boundary shapefile and associated attribute table) and query the attribute table to screen and select potential FPAs based on the following characteristics:

EFFECTIVE_DT (Effective date): select for dates between Jan. 1, 2014 and February 28, 2015 (dates most likely to have been harvested within our harvest window (March 2015-October 2015).

REGION_NM (DNR region): select for Northwest, Olympic, Pacific-Cascade or South Puget Sound (excludes eastside regions).

DECISION (Status of Application): select for APPROVED or RENEWAL (excludes applications that are not approved for harvest).

ALTERNATE_PLAN_FLG (Alternative Plan Submitted): exclude Y (excludes activities conducted under an alternative plan).

HABITAT_CONSERVATION_FLG (Application covered by Habitat Conservation Plan): select for blanks- (excludes activities conducted under a Habitat Conservation Plan).

CUTTING_OR_REMOVING_TIMBER_FLG (Involves cutting or removing timber): select for Y (excludes FPAs without timber harvest, e.g. road construction, chemical application).

EXEMPT_20_ACRE_RMZ_FLG (Application qualifies for less than 20 acre parcel RMZ prescription): exclude Y (excludes FPAs with RMZ harvest under special 20 acre parcel exemption).

HARDWOOD_CONVERSION_FLG (Hardwood conversion applications): exclude Y (excludes hardwood conversion applications).

TIMHARV_FP_TY_LABEL_NM (harvest type): select for EVEN AGE, UNEVEN AGE, EVEN/SALVAGE, UN/SALVAGE, EVEN R/W, UNEVEN R/W (excludes FPAs limited to right-of-way, salvage, or no harvest).

CMZ_PRESENT_FLG (channel migration zone): exclude Y (excludes RMZs with channel migration zone buffer present)

Step 2. GIS screening to select FPAs within 200 ft of a Type F or S stream.

Using WDNR GIS hydrography layer (from www.dnr.wa.gov/GIS), restrict the hydro layer to F and S segments and use the ArcGIS Near function to select the subset of FPAs from Step 1 with harvest within 200 ft of a Type F or S stream.

Step 3. Put list of selected potential FPARs units in random order.

Use an ArcGIS script to assign a random integer between 1 and 1000000 to each FPA from Step 2, sort on the random number.

Step 4. Examine FPAs in assigned order to identify potentially suitable segments.

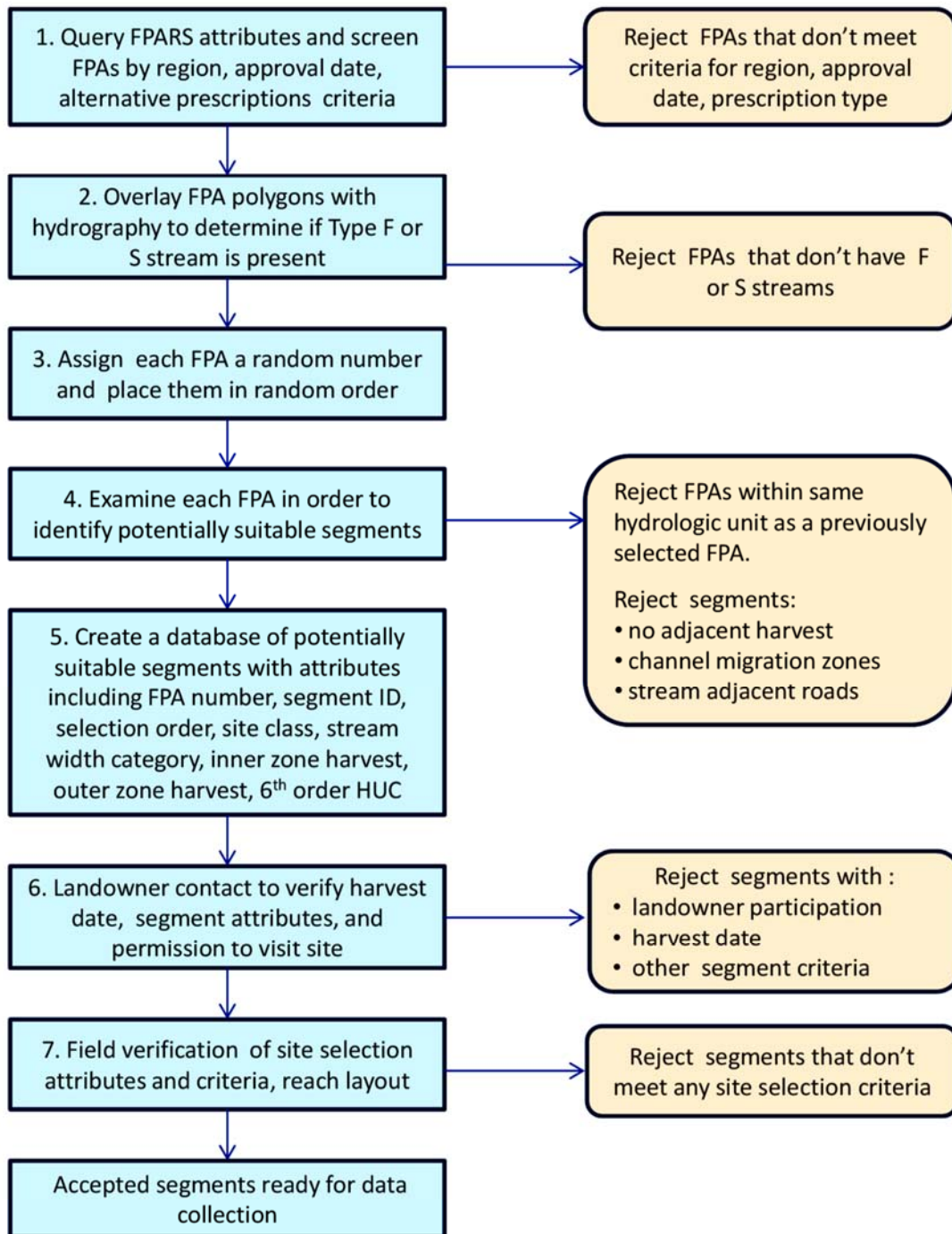
Working thru the randomized list of FPA numbers from the top, do the following:

- Overlay the FPARs unit boundary polygons on the WDNR hydrography to verify that there is a Type S or F stream in or immediately adjacent to the unit. Verify by examining the map included with the FPA pdf file. If no type F or S stream is present, reject the FPA.
- If F or S streams are present, overlay the 2015 NAIP imagery to verify that there is evidence of harvest. If not, reject the FPA.
- Overlay FPA polygon with GIS layer of USGS Hydrologic Units. Reject any FPAs that are within the same Hydrologic Unit as a previously selected FPA to ensure spatial dispersion and minimize potential for spatial autocorrelation.
- Use data in the FPA pdf file to reject FPAs for Habitat Conservation Plans, Alternative Plans or 20-acre exempt parcels that were missed in Step 1.
- If an F or S stream is present and there is evidence of harvest, use data in FPA pdf file (Table 21 and the attached DFC worksheets) to identify the stream segments with adjacent harvest. Reject any segments with Channel Migration Zones.
- Examine each segment using the map in the FPA pdf file and the NAIP photography to determine if there is a stream adjacent road through the Core or Inner Zones of the segment. Reject segments with stream adjacent roads.
- Using NAIP photography in GIS, measure the length of the segment. Overlay the segment with the USGS Hydrologic Unit (HU) layer to identify the 6th level HU.
- Create a database record for each remaining potential segment with the following attributes: FPA number, segment identifier, selection order, site class, stream width category, inner zone harvest type, outer zone harvest strategy, one-or two sided buffer, 6th order HU code.
- Assign segments to prescription variants.

Step 5. Collect data on attributes of interest for each of the selected FPAs.

Using the FPARs database, the pdf file for each FPA, the FPARs unit boundary polygons, and other GIS information (hydrolayer, NAIP imagery, DEM, SSHIAP) extract and record the data on each Type F or S stream segments identified in each FPA. Table 1 (next page) shows the data attributes and provides a brief description of the procedures to obtain the information.

Appendix Table C-1. Graphical depiction of the site selection process.



Appendix D. Example of RMZ Segment Layout

